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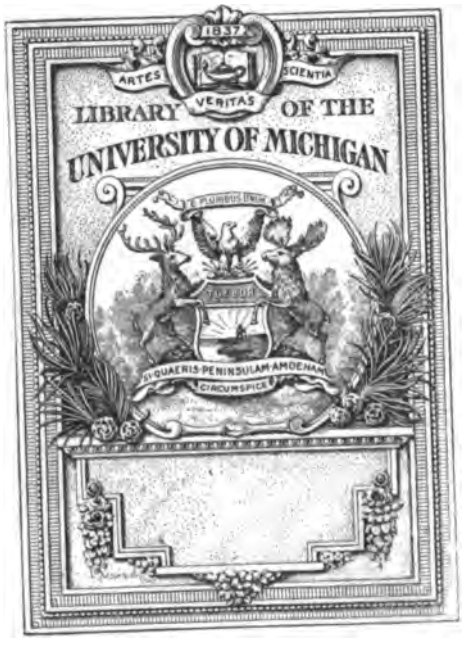
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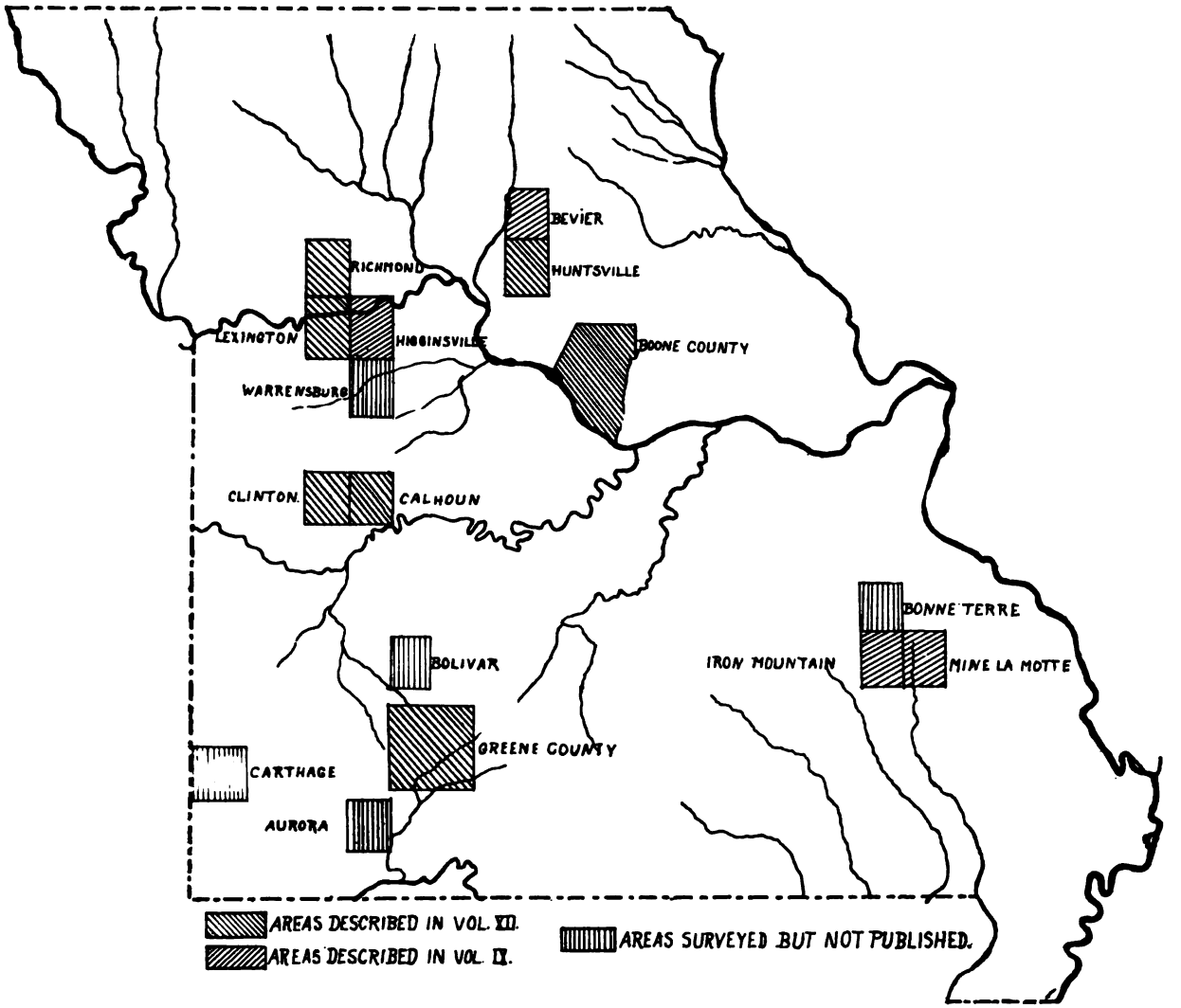
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BONNE TERRE
BOLIVAR
IRON MOUNTAIN
MINE LA MOTTE
GREENE COUNTY
CARTHAGE
AURORA
AREAS DESCRIBED IN VOL. XII.
AREAS DESCRIBED IN VOL. IX.
AREAS SURVEYED BUT NOT PUBLISHED.

MISSOURI

GEOLOGICAL SURVEY

VOLUME XII.

REPORTS ON AREAL GEOLOGY.

CHARLES R. KEYES,

STATE GEOLOGIST.

JEFFERSON CITY.

TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS.

1898.

BOARD OF MANAGERS.

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Ex officio President of the Board.

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LETTER OF TRANSMITTAL.

To the President, Governor Wm. J. Stone, and the Members of the Board of Manager, Bureau of Geology and Mines:

GENTLEMEN—I have the honor to transmit herewith for publication as Volume XII of the reports of the Missouri Geological Survey, the second installment of detailed areal reports comprising sheets 5 to 10, and also a paper on the Geology of Boone County and one on the Ozark Uplift, and to remain,

Your obedient servant,

CHAS. R. KEYES.

State Geologist.

172553

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PREFACE.

The field work within the areas covered by the Clinton, Calhoun, Lexington, Richmond and Huntsville sheets was done principally in 1890 and 1891. That on the Lexington area was begun in the early part of 1890 and the topographic work was furnished in July. The notes were platted and the map drawn the following winter. The drawing was subsequently lost and another one made in the winter of 1892–93. Before the second drawing was made the field work was revised, this being done in December 1892. The work was done, excepting the revision, by Gluck and the writer, the revision being done by the latter.

The field work for the topography of the Huntsville quadrangle was begun by Gordon in June 1890. As soon as the work on the Lexington sheet was finished he was joined by the writer by whom the work was completed in October. Gordon worked continuously up to the end of August when he was called home. He is responsible for that part of the sheet lying east of the meridian of Huntsville and between the lattitudes of Huntsvile and the Elliott shaft as well as for most of the township lying immediately northwest of the former place.

Work on the topography of the Richmond area was commenced in 1890 by a party in charge of the writer with Mr. M. C. Shelton as topographic aid and T. B. Marbut as camp assistant and rodman. The work was finished in June and the party was transferred to Randolph county where work was begun on the Bevier sheet. This was completed in August and the party was transferred to Henry county where work was begun on the Clinton sheet September 1. When the Clinton area was about half covered T. B. Marbut was made topographic

aid and with this increased force the area was covered by the middle of October. Work was immediately begun on the Calhoun sheet and was completed December 10, when the party left the field for the winter. The platting of notes and the drawing of the maps was vigorously prosecuted throughout the winter of 1892-93 and the topographic maps were ready for the engraver by the first of May, 1893. This work was outlined by Winslow, the field work was done under his direction and the topographic sheets were prepared for the engraver while he was State Geologist.

The data from which the reports on these areas have been written accumulated, the greater part of it at least, during the progress of the topographic survey. Part of this material was put in order and a preliminary draft of the roports on the Huntsville, Richmond and Clinton quadrangles was made in the winter of 1892-93 but it was shown to be necessary that a little more field work be done in order to clear up a few doubtful points. From the time the party took the field in the spring of 1893 until June, 1894, nothing further was done with these reports and this was the condition they were in when Dr. Keyes was elected State Geologist in May, 1894. At the time Keyes was elected to that position, the Board of Managers entered into a contract with the writer to complete the field work on these areas and prepare the reports. The field work was done in the summer of 1894 and the reports were written during the latter part of that year.

At various times during 1895 these manuscripts were revised and slight changes made in the order of treatment at the suggestion of the State Geologist. In the latter part of 1896 the report on the Calhoun sheet was printed and that on the Clinton sheet, in the early part of 1897. In May, 1897, the maps were sent to the engraver but before the work had progressed very far Mr. John A. Gallaher became State Geologist. Immediately afterward the editing of the report was placed in the hands of the writer.

The drawings for the page cuts were made chiefly by the late Mr. E. H. Lonsdale and those for the plates of cross sec-

tions by Mr. T. B. Marbut. The original drawings of the topographic maps were made by M. C. Shelton, T. B. Marbut and the writer.

Like the previously issued numbers of this series of areal reports the attempt is made to include nearly all the geological details that were recorded in the field. The first few pages of each report is given up to general considerations in which the topography and geology of the region is sketched on broad lines, and this is followed by a discussion of the general features of the particular area under considration in sufficient detail for the general reader. After that the outcrops are described in detail, and the individual beds are correlated for the whole area. This part of the report is intended for the prospector or prospective investor, and the attempt is made to give the details so full that none need hesitate, with the report and map in hand, about the evidence for coal beds at any given place and the conditions under which they may be found.

The latitude and longitude of each sheet is that of the corresponding sheet of the United States Geological Survey. The positions of the township lines were obtained from the same source. The section lines were placed in the townships from the original plats and notes of the Land Office survey. The details of the maps are referred exclusively to the section lines and their subdivisions. Almost every section corner within the areas of these sheets was located, and by far the greater number of the subdivision corners. Accurate trigonometrical surveys will not, therefore, make the topography inaccurate. The land corners may be shifted, but since the details of the maps are referred to these corners their relations remain the same, whatever may be the positions of the latter.

The vertical control is based on spirit levels, which were run over most of the wagon roads, and on barometric data for intermediate positions. In the Lexington and Richmond maps the levels started from Missouri River Commission bench

marks. In the other sheets we depended upon the railroad levels.

The report on Greene county is the product of many years of observation by Prof. Shepard. The beginning of the work in the region extends back to the time when he became professor in Drury College, nearly twenty years ago. Up to 1890 the work was done at his own expense during the summer vacations and while conducting class excursions during the school year. When the Geological Survey was reorganized in 1889 Prof. Shepard became a volunteer assistant and was assigned to the work in Greene county. With the exception of a small amount of work done by Robertson in 1890 the field work for the whole report was done by Prof. Shepard without assistance. The first draft of the report was written as early as 1893, but on account of lack of funds it could not be published when first prepared. Between 1894 and 1896 additional work was done and the report entirely re-written. The printing of the report was finally begun in the early part of 1897 and the first 60 pages were printed and the proof read by Dr. Keyes while he was State Geologist. Printing was stopped when the change in the administration of the Survey took place and was not resumed until a few months ago. The drawings for the base of the Geological map were made by Mr. T. B. Marbut and those for the plate of cross and columnar sections were made by the writer.

Many things in this report show the lack of a comprehensive view of the many parts during its preparation and publication. The printing was commenced two years ago and the Clinton and Calhoun sheets were printed and the proof read by Dr. Keyes. The printing of the report on Greene county was commenced soon after that, and the first sixty pages had been set up and corrected before the retirement of Dr. Keyes from the survey. The printing of this report was commenced before any of the drawings had been prepared, and when the matter was turned over to the writer it had to be stopped until the drawings were prepared and the engraving done. This was ready about June 1 last, but the printing was not re-

sumed until in September. On account of the fact that the editor was in one place and occupied with other duties and the printing was done in another, a perfect correlation of parts has not been effected. This has been aggravated by the intermittent way in which the printing has been done. The numbering of the plates and cuts is not wholly consecutive. The use of terms is not the same throughout the report. For example, in the Clinton and Calhoun reports the word *vein* is used repeatedly for *bed* when discussing the coal deposits. In the titles of the Clinton and Calhoun reports, the word *sheet* has been used while the word *quadrangle* has been used in those of the other reports. This term has been in use by the United States Geological Survey for the last year and it suits the case so well that it has been adopted for the reports of this volume, whose printing was commenced since the term was proposed.

C. F. MARBUT.

Columbia, Mo., December 23, 1898.

GEOLOGICAL SURVEY OF MISSOURI,

CHARLES R. KEYES, STATE GEOLOGIST.

VOL. XII--PART I.

SHEET REPORT NO. 5.

A REPORT ON

GREENE COUNTY

BY

EDWARD M. SHEPARD.

PUBLISHED BY

THE GEOLOGICAL SURVEY.

JEFFERSON CITY:
TRIBUNE PRINTING CO , STATE PRINTERS AND BINDERS,
DECEMBER, 1898.

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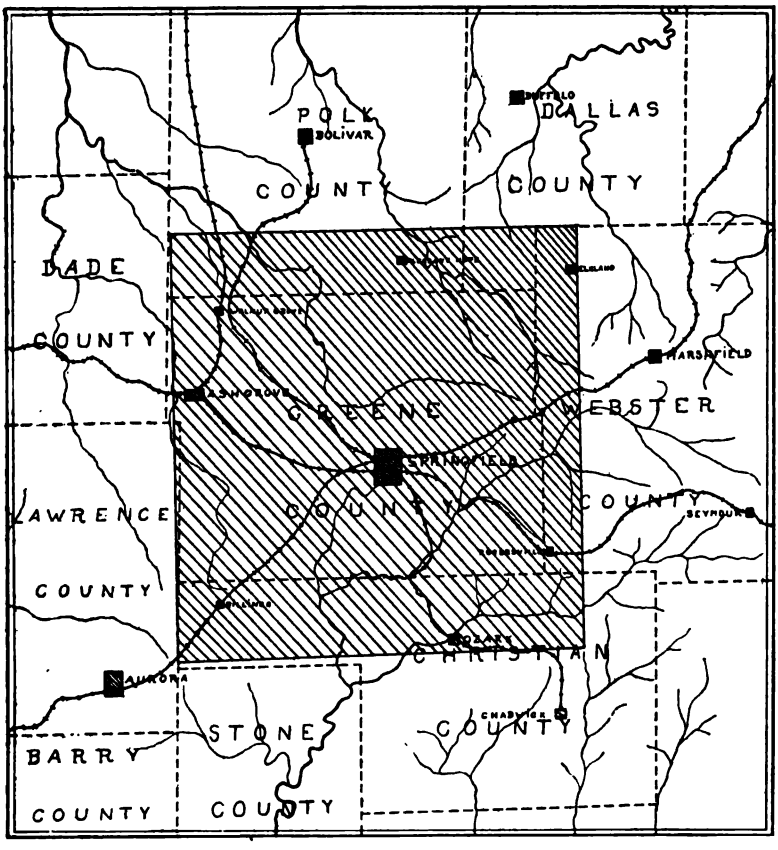
INTRODUCTION.

LOCATION AND AREA.

Greene county is in the southwestern part of Missouri, about 60 miles from the western boundary of the state and about 40 from the southern. It is bounded on the north by Polk and Dallas counties, on the east by Webster, on the south by Christian, and on the west by Lawrence and Dade. In outline it is nearly square.



PREVIOUS WORK.

Until recently little geological work had been carried on in Greene county. The earliest search for mineral wealth in the region was in connection with the expedition of De Soto; and it is believed that this explorer spent some time during the winter of 1541-2 within the present limits of Greene county. Little is known of later Spanish or of the French travels in this region. No observations of importance concerning the mineral resources were made until 1819, when Schoolcraft * visited this part of the state. He reached a point on the James river about twenty miles above the mouth of the Finley. Here he erected a cabin at the place now known as the Phelps mines, and spent the month of January. His descriptions are very accurate and extremely interesting, although there is little geological detail included.

Featherstonhaugh, according to his "Geological Report on the Elevated Country between the Missouri and Red Rivers," evidently did not traverse this part of the state. King * very accurately describes the formations in the territory adjacent to the area under consideration, but did not go far enough south to enter it. Swallow * gives a cross-section from Neosho to Springfield; and also describes a section obtained east of Gresham (Tp. 31 N., R. XXII W., Sec. 16). In his "Geological Report of the Country along the line of the Southwestern Branch of the Pacific Railroad," published in 1859, he also considers briefly different counties and the account is accompanied by a small general geological map of the areas contiguous to the railroad.

From time to time references and short accounts of the resources of the county have appeared in the various atlases and histories of the state and county, but for the most part these are unimportant geologically.

---

*Scenes and Adventures in Semi-Alpine Region of Ozark Mountains of Missouri and Arkansas, p. 11, 1853.

*Geological Reconnoissance in Country adjacent to Osage River; Missouri Eleventh Gen. Assem., 1st. Sess., Sen. Jour., pp. 458-525, 1840.

*Geol. Sur. Missouri, 1st and 2nd Ann. Reps., p. 204, 1853.

PHYSIOGRAPHY.

TOPOGRAPHY.

This area lies upon the central portion of the crest and flanks of the Ozark * uplift. The present surface features of Greene county are due almost entirely to the erosion of streams, modified, to some extent, by flexures. The rocks are mainly limestones, with intercalated beds of chert, and some sandstones and shales. They vary greatly in hardness, crystalline structure, texture and chemical composition, and are variously acted upon by physical agencies—such as flexures, which produce shattering, and thus render the breaking down of the formations more easy; frost, which still further facilitates this breaking down; the chemical action of percolating waters; and the weathering out of soft layers and the undermining of beds above. All of these conditions help to modify the topographical features of the country, and each formation, according to its peculiar structure, exhibits special characteristics due to the action of one or more of these agencies, as will be seen in the particular description of each horizon.

The great watershed of the Ozark uplift which is, in general, followed by the St. Louis and San Francisco railroad, divides the district into two slopes. The waters on the north flow into the Missouri; those on the south into the White river. The main divide is rather narrow in the eastern end of the area, the country falling away rapidly on both sides, forming the rough broken area around the headwaters of the Pomme de Terre and James rivers. To the west it rapidly broadens, forming a wide, rolling plateau.

The two slopes present distinct topographical features; and each exhibits minor sub-divisions. The one to the south

*The origin of the name "Ozark" is given by Mr. Featherstonhaugh in his book entitled "Excursions through the Slave States," in 1834-35, p. 63. He says, "It was the custom of the French Canadians to abbreviate all their names. If they were going to the Arkansas mountains they would say that they were going 'Aux Arcs.'" and thus these highlands have obtained the name of Ozarks, from the American travelers.

is divided by the James river, and still further to the southeast by the Finley, the two valleys being separated by a well-marked divide. South of the last mentioned stream is a cherty ridge district, bounded far to the south by the White river. The northern slope comprises four well-marked districts: (1) The post-oak flats, or central plateau, along the crest of the Graydon-Northview monocline, (2) the Morrisville-Brighton divide, (3) the Pleasant Hope-Sand Spring district, and (4) the Elkland plateau, in the northeast.

TYPES OF SURFACE RELIEF.

Central Plateau. The narrow eastern portion of this plateau, between Strafford and Northview, is rough and rugged. It reaches an altitude of over 1500 feet above the sea level, falling off abruptly to the headwaters of Pomme de Terre and Sac rivers on the north, and the tributaries of the James on the south. The general southwesterly dip of the strata, modified locally by slight flexures, brings the lower Burlington to the surface. Where the streams have cut vigorously, narrow gorges are formed with barren cherty slopes, which are generally covered with stunted timber. To the west of Strafford, and toward Springfield is a beautiful, rich farming country which rapidly merges again into cherty lands both to the north and south, where South Dry Sac and Pierson creeks cut through into the lower beds. The Kickapoo prairie stretches out southwesterly from Lyman, and forms a broad plain between Wilson creek and the James. This, with Grand prairie to the west, forms the finest farming land in the county, and one of the most fertile areas in the Southwest. The National boulevard and cemetary near Springfield lie in about the middle of this beautiful region.

Toward the trenches cut by the streams the country becomes rugged and cherty, the lower Carboniferous limestones, which once covered this part of the area, having been carried away by erosion. Surrounding and penetrating this district on all sides from the Sac and James are small streams and branches, usually heading in springs or swampy uplands.

When a low enough level is reached to allow of the escape of the subterranean waters, springs of various sizes abound, always increasing in volume in approaching the lower beds of the upper Burlington formation. The marvelous system of underground drainage in this cavernous limestone, and its striking effects upon the topography, is still further indicated by the numerous sinks which are usually associated in groups having the same general trend, and generally marking the course of subterranean streams. The sinks occasionally have small streams appearing at one end, flowing through the center and disappearing at the other end, as is seen in one on the McDaniel farm, south of Springfield (Tp. 28 N., R. XXII W., Sec. 12, Sw. qr.); also in the city of Springfield, at the southwest corner of Cherry and Dollison streets. The last mentioned sink is used by the city for the conveyance of the sewage of the neighborhood. In Tp. 29 N., R. XXII W., Sec. 32, N. ½, is a large sink containing a cave opening, in the bottom of which a considerable stream of water flows and disappears in a cave at the other end of the sink. East of Republic, on the Noe place (Tp. 28 N., R. XXIII W., Sec. 28, Se. ¼ of Sw. qr.,) a well was sunk and opened into a cave, through which a stream of water flows at a depth of about 20 feet. In this the owner has placed a ram which pumps water for his house and farm purposes. Numerous other caves might be mentioned, especially in the city of Springfield, where underground currents have been struck by drill-wells. This system of underground drainage is further illustrated by the great streams that flow from small caves in the upper Burlington formation around the limits of this district. The large and remarkable caves of this region are almost wholly confined to the lower beds of the upper Burlington limestone. The great agent, then, in developing the topographical characters of this district has been the remarkable system of underground watercourses, which has formed the sinks so characteristic of the central plateau, as well as of the narrow gorges and ravines penetrating deeply on all the borders of the district. By the study of the sinks the inevitable conclusion is reached that they are the

beginnings of the deep and narrow gorges which are so abundant.

To the west of the Kickapoo prairie is the narrow valley of Wilson creek which has cut deeply into the central district, and which separates this from the Grand prairie, the latter spreading out as a great V-shaped belt from Springfield. One arm has a northwesterly trend, forming an upland divide between Sac and Clear creeks, and extends, with a width of from two to four miles, to Cave Spring, where it is again divided by Asher creek. The broader southwesterly fork reaches to a point a little beyond Republic, and varies in width from two to five miles. Due west of Springfield, in the region around Nichols Junction, and north of Republic, is found some of the choicest rolling prairie land in the district. The fine, substantial farm houses, thrifty orchards and well-tilled fields, extending as far as the eye can reach, are the most convincing proofs of the fertility of the soil.

James-Finley Divide. Somewhat similar characters as those already described in the Great Divide are found here. In the east is a belt narrowed by Panther creek and Sayer branch on the north, and the Petelo on the south. It is underlain, mainly, by the lower Burlington limestone. In the vicinity of Rogersville, and especially to the east and southeast, is a broad rolling prairie, containing, near the crest of the divide, excellent arable land, but becoming more cherty and wooded on the slopes. East of the station, the Kansas City, Ft. Scott and Memphis railroad follows the crest of this watershed for a number of miles outside of the area, reaching an altitude of 1530 feet before leaving the district.

In Washington township, to the west of Rogersville, the plateau rapidly merges into another which presents somewhat different aspects. The drainage is poor and the surface of the country over the greater part is an elevated plain, having a slightly rolling surface, covered by post-oak flats, except in two small areas which are occupied by prairies. The highest point in this township is three-quarters of a mile south of Harmony church, where the altitude reaches about 1540 feet.

This divide narrows westward, forming abrupt slopes and bluffs toward the Finley on the south, where the lower Burlington prevails and the characteristic shaly limestone and chert slopes of the lower beds of the upper Burlington are exposed. The James river to the north of the central portion of this district does not cut through these strata.

Along the Finley, the mural bluffs of Burlington limestone break the monotony of the cherty slopes. The very decided dip of the rocks to the southwest favors subterranean drainage and results in numerous caverns. The caves are more frequent near the base of the upper Burlington limestone, where the underground drainage is strong and due to the dip of the rocks. Thus numerous caverns are found on the south slope of the James-Finley divide and not on the north slope; also near the foot of the same limestone formation on both sides of the central plateau. A noticeable increase of the chert towards the south leaves its impression on the rugged flint hills on the south side of this divide. The soil is residual and completly hides the rocks underneath. It seems to be an area in which surface or subterranean drainage is lacking, and in which has been formed a clayey, impervious covering to the indurated beds.

Chert-Ridge District. A small portion of this remarkable district is contained within the area covered by this report, and it comprises the southern part of township 27 north, ranges XIX, XX, and XXI west, south of the Finley. Far enough away from the breaks of the stream, the upland district, particularly around the town of Sparta, is a fine farming country. To the south, however, there is a series of long, deep and narrow gorges alternating with narrow, usually heavily-wooded cherty ridges that stretch down toward Swan creek. Erosion has cut deep, and the high, narrow ridges and deep canyons characterize the area far to the south. In the gorges are located many small mining camps, some of which have been quite productive in the past, and many of which have good promise for the future. The scenery from these ridges

is very fine, and beautiful vistas of wooded hill and valley frequently greet the explorer.

The slope to the north toward the Finley is marked by the usual characteristics of cherty ridges alternating with the deep gorges and ravines. The bluffs are largely on the north side of the stream.

Post-Oak Flat District. This is a somewhat arbitrary division, lying on and to the south of the crest of the Graydon-Northview monocline, with a prolongation, including Robberson prairie, lying west, southwest and east of the town of Ebenezer. It is, perhaps, the most difficult area to describe and map, owing to the faulting and tilting of the strata, which constantly brings different formations to the surface, and out of their proper position along the course of this monocline.

The above name has been given to this district because of the presence of a narrow belt of country south of the crest of the monocline, which is largely made up of long, narrow patches of level, unproductive land, covered with the post-oak. Except in the driest season, when it has an ash-colored, powdery soil, it is a damp, clayey, frequently cherty, upland. The soil is residual, and completely hides the rocks underneath. It seems to be an area in which surface or subterranean drainage is lacking, and in which has been formed a clayey, impervious subsoil, covering, at various points, First Magnesian, Hannibal and Burlington beds.

Northeast from Strafford, on the Marshfield road, a narrow ridge of sandstone, capped by river conglomerate, is found. This peculiar bluff rises to a height of 110 feet above the stream. From this bluff, a ridge of post-oak flat country stretches out on each side of the road. Westward, it runs down quite abruptly, both to the north and south, the view on the north side overlooking fine stretches of farming land known as Locust prairie, and parts of the Pomme de Terre valley beyond. Still further west, toward Ebenezer, the barren belt is narrowed and broken by the beautiful farming lands of Robberson prairie, south of the Ebenezer-Marshfield road. This prairie spreads out to the southwest and west of Ebenezer,

and includes the uplands bounded by the great curve of the Sac river to the south.

North of Hickory barrens, on the Springfield-Buffalo road, the barren country forms the crest of the monocline. This crest frequently breaks very abruptly from a flat, level area on the south, by a precipitous or abrupt slope, to the plain of the valley below.

At the union of King branch with dry Sac, the bluff scenery is remarkable. The ridge, or "back-bone," rising from 120 to 160 feet above the stream, terminates abruptly in a narrow zone between the two streams. The summit is capped by the upper Burlington limestone, and presents a striking castellated appearance. The Presley Hill system of faults passes through this bluff, and a few square miles of the territory in this region offers the finest opportunity for the study of structual geology, of any portion of the district. The rugged valley of the Sac river is well shown from the summit of this bluff. To the north are noted the irregularties of the surface between this point and the Morrisville-Brighton road. To the south, the narrow wooded slopes of King branch vary the beauty of the scene. About two miles south of this bluff (Tp. 31 N., R. XXII W., Sec. 27), is the remarkable mound of circumdenudation known as King butte. Around the base of this mound is a broad, barren terrace of Sac limestone, from 80 to 150 feet wide. Above this rises an abrupt naked slope of about 40 feet of Hannibal shales, the whole being capped by a few feet of Hannibal sandstones and remnants of Chouteau limestone, the latter having an area of about 30 by 40 feet. The view from the summit of this elevation is far-reaching and beautiful. To the northwest, in the distance, is a high ridge. Between the mound and this ridge is the tortuous, wooded valley of the Sac. About half a mile west of the mound is the Bolivar road, and from that point to the ford on the Sac is exposed a remarkable series of faults, which will be described in the chapter on geological structure. To the south, on the Bolivar road, and west and southwest to the Morrisville road, is a barren stretch of post-oak country, underlain by the lower Bur-

lington and the First sandstone. From this point west, across Asher creek, where is found some fine bluff scenery, the First Magnesian limestone and First sandstone form broad stretches of barrens.

Two miles south of Gresham, near the Matherly place (Tp. 31 N., R. XXIII W., Sec. 24), is a very beautiful overhanging bluff of Second Magnesian limestone. The Sac formerly made a great bend at this point, and the bluff formed its north bank, but the stream now flows nearly north and south, leaving its former rocky barrier standing at an angle to its present course. The rocks here rise to a height of 120 feet above the bottom land. The softer layers of the Magnesian rocks form a vertical wall capped by the upper honeycombed silicious beds of this formation which project, in some places, 20 feet beyond the wall below. Above this bluff the general surface of the country has a rugged appearance usually given by the presence of the honeycombed layer.

The Indians, as in many other places, have taken advantage of the beautiful and sightly situation and used the summit of this bluff for one of their burying grounds. Numerous graves, mounds covered with piles of flat stones, have been found, as well as various other reminders of their former occupation of this region. West of this point, the southerly slope of the surface brings up a broad belt of the Hannibal beds, which cover a considerable area, and which form the characteristic post-oak flats. Parallel with this to the north, is a narrow belt of First Magnesian limestone and First sandstone (mainly the latter) having a northwest trend. In Tp. 31 N., R. XXIII W., Sec. 8, near the center of the northeast quarter, at the edge of Polk county, a ferruginous sandstone forms a narrow ridge, or "backbone," continuous with the ridge at Graydon Springs. Here a little stream cuts through the ridge, exposing the First sandstone, upon which the ferruginous sandstone rests, a juxtaposition which is, at first sight, somewhat confusing. The ridge very closely resembles the one at Strafford. The sandstone has the peculiar pitted and false-bedded structure and varriegated coloring so char-

acteristic of this formation. The "backbone" is over 100 feet above the level of the surrounding country, and the rocks along its crest are very much tumbled and broken.

Morrisville-Brighton District. The Bolivar-Marshfield anticline is broken up into minor folds or swells, and it has been found convenient to make these folds the basis of the topographical divisions of the region. The narrow belt is quite distinct in the northwestern corner of the region between Morrisville and Brighton. Its continuity is more or less distinct through Fair Grove, and southeastward nearly to the east line of the area. It forms a narrow belt but a few miles wide, and is characterized, in the northwestern corner, between Morrisville and Brighton, by an elevated ridge of upper Burlington limestone, which is hardly important enough to be regarded as a plateau. The tributaries of the Sac on the south, and Slagle creek on the north, cut into the upper Burlington limestone with characteristic gorges. These soon cut through the upper Burlington, and the lower Burlington, which is either very thin or absent, and expose the long slopes of the Hannibal shale, as is finely exhibited on the Morrisville-Springfield road, between the former place and the Sac. Passing eastward along the crest of the anticline, the general southwesterly dip of the rocks through this whole area, as before mentioned, gradually brings the lower formations successively to the surface. For example, south of Pleasant Hope there is a considerable slope of the Hannibal alternating with more elevated ridges of upper and lower Burlington, succeeded by the Devonian, First Magnesian and First sandstone, the latter forming quite a district in the vicinity of Fair Grove and especially west of this place, where the Little Pomme de Terre cuts through this fold. Here quite a number of interesting mounds mark the course of the ridge. They are usually capped with the more durable Hannibal sandstone, and form highly characteristic features of the landscape. The mound one mile and a half southwest of Fair Grove is capped with the sandstone conglomerate. It is a prominent feature of the country for miles around, and were it not so densely wooded,

it would give a beautiful view of the surrounding region. Several other mounds are situated on the elevated region between the Big and the Little Pomme de Terre. A limestone forms a small portion of the crest of the plateau at this point, and the beautiful slope eastward toward Pomme de Terre and the rocky western course of the stream is referred to elsewhere. The last prominent feature of this crest toward the east is northwest of Northview (Tp. 30 N., R. XIX W., Sec. 9), where there is a big mound capped by the sandstone conglomerate, and similar in structure and general appearance to the Fair Grove mound.

Pleasant Hope-Sand Spring District. This region is well marked at a number of points, but the continuity of the ridge has not been so well established as in the other districts. Its eastern crest is situated near Sand Springs, where an elevated tract of First sandstone occurs, with its characteristic stunted vegetation. Passing westward, one of the poorest agricultural districts of the area is seen, the sandstone being rapidly replaced by the denuded honeycombed blocks of the upper silicious layer of the Second Magnesian, which gives the country a very desolate appearance. At the ford, where the Fair Grove-Elkland road crosses the Pomme de Terre (Tp. 31 N., R. XX W., Sec. 13), the Second sandstone appears, and gives the best exhibition of this formation within the area. For several miles to the west from this point, the Pomme de Terre flows just south of the crest of this ridge, and the country is rough and generally unfavorable for agricultural purposes. Just over the line to the west, in Polk county, Newton, Goodnight and Boyd mounds strikingly mark this fold. The first, Newton mound, is, perhaps, the most picturesque one in the district. It is capped with the conglomerate, and stands nearly 200 feet above the Pomme de Terre, which flows along its east and south sides. On the very steep slope to the river, fine sections are obtained of all the formations from the Second Magnesian up to the Chouteau, which lies just beneath the sandstone conglomerate. The summit of this mound commands views of the surrounding country in almost every

direction, and especially to the north, east and south. Good-night mound, one and one half miles to the west, is also capped with the conglomerate. The Pomme de Terre bends abruptly to the north, where it crosses this ridge midway between Good-night mound and Pleasant Hope. The conglomerate outcrops just east of the latter place, at the southern end of the First sandstone plateau, and extends westward along the western edge of the main divide.

Pleasant Hope has an altitude of about 1170 feet, being 175 feet below the city of Springfield. Probably the best farming land underlain by the First sandstone is found on the plateau to the northwest of Pleasant Hope.

Elkland Plateau District. This broad belt lies in the northeastern part of the area under consideration and forms a small portion of the Bolivar-Marsfield anticline. It is almost wholly underlaid by the Second Magnesian limestone and the First sandstone. A small outcropping of the Second sandstone is shown in Gibbon creek, one of the small tributaries of the Niangua. To the west, along this fold, the country is rough, cherty and poor, but towards the middle beds of the Second Magnesian some fine farming land is found. This fertile condition predominate whenever these middle beds occur, and the surface is gently rolling and slightly diversified. Where erosion has laid bare the cherty lower beds of this formation, or where its silicious, honeycombed upper beds underlie the surface, the rugged, desolate and characteristic barrens prevail, and are usually left to pasture and stunted timber. Several miles west of Elkland the divide is formed of the First sandstone, constituting generally a more or less barren district, covered with stunted timber and scant vegetation, with occasional clearings occupied by small and comparatively unproductive farms. The roads across this plateau form long stretches of sandy wastes. In Tp. 32 N., R. XX W., Sec 17, S. ½, a small outcrop of upper Burlington limestone, surrounded by a Hannibal slope, marks a point near the crest of this uplift.

HYDROGRAPHY.

SURFACE DRAINAGE.

As already stated, the great divide, or watershed, of the Ozark uplift runs diagonally through the middle of this district. The drainage on the north side is into the Sac river, through its numerous tributaries, passing out of the northwest corner of the area. The Pomme de Terre drains the greater part of the northeastern corner, while the extreme northeastern part is drained by a few small streams that empty into the Niangua. The drainage is finally into the Osage and Missouri rivers. South of the divide, the James river and its tributaries constitute the chief drainage system. These waters ultimately find their way through the White river into the Mississippi. As a good sample of the abruptness of this watershed, the drainage from the south gutter of Commercial street, in the city of Springfield, runs through Wilson creek and the James and White rivers into the Mississippi; while that on the north side of the street flows northward into the Sac, Osage and Missouri rivers. This abruptness is equally great at many other points to the east.

James River. The area included by this system virtually embraces all the territory south of the grand divide. The James has its source some 15 miles to the east (Tp. 29 N., R. XXII W., Sec. 24) and pursues a generally southwesterly course until it receives the waters of Wilson creek, at which point it bends sharply to the south and southeast, and leaves the district in Tp. 27 N., R. XXII W., Sec. 32.

Upon the varying thickness and texture of the rocks of the geological formations depends the breadth of the valleys and the angle of the slopes. In Tp. 29 N., R. XIX W., where the immediate valley of the James is in the Second Magnesian limestone, are found low, rounded hills and slopes terminated by ledges of First sandstone. These form, in places, narrow escarpments, which are frequently cut into on both sides by narrow cherty gorges, the slopes of which, where they extend far enough to reach the lower Burlington, are usually quite

abrupt. In these instances, the Burlington chert, washing down and covering the surface, makes it difficult to obtain the outcroppings of the Chouteau and Devonian formations which are just below. Above the narrow sandstone escarpment, the valley frequently broadens into excellent farming lands.

Among the first tributaries that the James receives may be mentioned Welch branch, fed by a number of springs. To the west is another branch that flows down Bucksnort hollow in a southeasterly course. On the south side of the river, North Carolina creek, which rises outside of the area, flows through, a very pretty valley of bottomland and discharges its waters into the James near Compton. Dry branch, south of this town flows in a westerly course through two or three sections into the James. The most important tributary in the township is Panther creek. This stream rises several miles to the east of the area flows in a general northwesterly course and unites with the James at Panther Valley.

Taylor township is one of the best drained districts of the area. In it the James receives the waters of several large creeks which are fed by numerous springs. Within a quarter of a mile from where it enters the township this stream has added to it the waters of Davis creek, which are made up of large number of spring branches rising in the northeastern part of the township and flowing in a general southerly direction From this point the James takes a meandering course through the southern third of the township. Besides Davis creek, on the north, there are also Danforth, McGraw and Hagan creeks, all rising from numerous large springs. From the south, in this township, Sayer branch, rising south of Henderson, at Bryan spring, flows to the James in a northwesterly direction. Turner creek drains the southwest corner of the township.

The southeast portion of East Campbell township is mainly drained into the James through Pierson creek which has its source in several large springs. This creek flows in a general southwesterly direction. Galloway creek is the only tributary of any size in Clay township. It flows southward, receiving the water that flows from Fisher cave. This

township is noted for its caves, springs and sinks and has a very remarkable underground drainage. A considerable number of small spring branches flow for a mile or more and sink to some underground channel through which they are conveyed to the James. The most noticeable are those that disappear east of Gates. The great Boiling spring (Sec. 16) and the Cave spring at camp Cora (Sec. 30) are the outlets of some of these underground streams. From the point where it leaves this township the James has an exceedingly tortuous course westward along the line between Christian and Greene counties until it receives the waters of Wilson creek. In addition to numerous small spring branches, the only tributary of any size is Mack creek, which rises south of Turner and flows in a southwesterly course through a narrow, deep valley with numerous tributary branches that issue from narrow ravines.

Next to the Finley, *Wilson Creek* drains the largest area of any of the branches of the James. It has a generally southwesterly course to its union with that river. Its volume is increased by the "Jordan" which flows through the city of Springfield and merges with Wilson creek on the Peacher farm (Tp. 29 N., R. XXII W., Sec. 27, Sw. qr.). On account of receiving the sewage from the city, the waters of this creek are very impure and turbid. Townsend creek has its source in the Goose pond and flows westwardly into Wilson. One mile below the juncture, the latter stream sinks for a short distance. Robberson branch and Tyrell creek, the first rising one mile southeast of Republic, and the second near Billings, flow west and unite with Wilson creek about one mile above its junction with the James. Both Wilson creek and the James have changed their channels near the mouth of the former within the last few years. From this point to where the James leaves the district, there are no streams of any importance, but many springs add to its volume.

Finley River, draining the greater part of the southeastern townships, flows in a westerly course. Besides a number of large spring branches, but three tributaries of prominence flow into it. These are Petelo (shot pouch), Parched Corn and Elk

creeks. Along the valley of Elk creek are the somewhat noted Elk Valley and Alma mines.

Sac River drains about the same extent of territory in the northwest as the James does in the southeast. It empties into the Osage just west of the Osceola, in St. Clair county, and is mainly made up of the West Sac, the Main Sac, and the North Sac.

West Sac is formed by the union of Pickerel, Pond and Clear creeks. These streams drain the center of the west portions of the district.

Main Sac, which leaves the district near the northwestern corner, has a general northwesterly course. It is made up of Asher creek, North Dry Sac, Sims branch and South Dry Sac. The river has its source at the Norton, Piper and Dishman springs in Jackson township, Greene county. The two braches formed by these springs flow in a generally westerly course until they unite with South Dry Sac. The latter has its source in Thornton spring, and flows through a narrow valley with cherty slopes, westward to its junction with the main stream. It is supplied with many large springs and receives the waters of Fulbright branch, which has its source at the McKoin and Doling Park springs, just north of the city limits of Springfield. The water supply of the city is derived from the Fulbright spring the surplus of which passes into Fulbright creek. The course of Sac river up to this point is through a narrow valley. The current is generally rather sluggish particularly near the head of the stream, and the slopes are cherty and the soil poor. Near its source it passes through the post-oak barrens. From its junction with South Dry Sac its course is northward, the bluff scenery becomes more rugged, the current more rapid, and the valley frequently broadens out, forming broad floodplains. There are excellent locations for mill sites along the course of the river. Its valley is cut into by numerous gorges eroded by the water from the large springs which constantly add to its volume. Only three tributaries of any length run into the Sac until it is joined by the North Dry Sac at the edge of Polk county. These are Ritter Spring, Leather and Birdeye creeks.

North Dry Sac has its source in the Headlee springs. It has a northwesterly course, receiving the waters of numerous small spring branches until its volume is considerably increased by the addition of Sims branch. The valleys of these two streams are rather narrow and contain a good deal of rough country, although here and there are some rich bottom lands. One-half mile west of the union of Sims branch with the North Sac, the latter is joined by King branch. A precipitous ridge stands at the point of junction. The Fender branch, rising southwest of Pleasant Hope, discharges into North Dry Sac. A quarter of a mile to the west, Brighton branch, flowing due south from the town of Brighton, adds a small amount of water. Besides numerous springs and small spring branches, the only other stream of importance that helps to swell the volume of North DrySac is Asher creek.

Asher Creek drains the greater part of townships 30 and 31 north, range XXIII west, running nearly through the middle of these two townships. It has its source in Tp. 30 N., R. XXIII W., Sec. 14, Se. qr., on the high upper Burlington plateau. It flows several miles in a slight depression in the upper Burlington limestone, and is there a sluggish, turbid stream. In the vicinity of the town of Cave Spring, several large springs add materially to its volume, and from this point onward its current is much more rapid. It has eroded a deep, narrow valley, and numerous streams from either side add their waters, which gives to Asher considerable volume before it unites with the Sac.

Slagle Creek drains that portion of the district north of Brighton and Morrisville, and flows into the Sac near Orleans.

Pomme de Terre River. This stream receives the waters from the greater part of the northeastern portion of the district. The headwaters have a northwesterly course, but after leaving the area the river has a northerly course, emptying into the Osage five or six miles above the town of Warsaw. Several small branches unite south of Bass (Tp. 30 N., R. XX W., Sec. 1) and drain the greater part of Grant township in Webster county. Their valleys are rough. A striking dif-

ference is noticed between the land west of Bass, in Greene county and that to the east in Webster, the former being generally, beautifully rolling prairie land with very gentle slopes to the river, while in the latter the slopes are abrupt and precipitous and covered with great blocks of the honey combed chert of the Second Magnesian limestone. With the exception of several small spring branches, no stream is found until the Little Pomme de Terre is reached. This tributary has its source in the Meyers and the Womack springs in Jackson township, Greene county. It flows through broken country and receives, as its largest branch, Fair Grove creek. Skillet creek flows west from the town of Skillet, in Dallas county, and is the main tributary to the Pomme de Terre on the north Potomac creek, rising southeast of Pleasant Hope joins the Pomme de Terre just before it leaves the district.

Niangua River. The extreme northeastern part of the area, around Elkland, in Webster and Dallas counties, is drained through four branches, into the Niangua, a stream flowing outside of the limits of the district. The first of these is Sand Spring branch, which rises just at the edge of the area. The second is Gibbons branch, in the northern tier of sections in Tp. 31 N., R. XIX W. The third is Patterson branch, rising in Tp. 32 N., R. XIX W., Sec. 28, and leaving the area in its extreme northeastern corner. The fourth is Greasy creek, which leaves the district in Tp. 32 N., R. XX W., Sec. 13. These streams all drain the elevated Second Magnesian and First Sandstone plateau. They are more or less sluggish, and flow through narrow, rather rough valleys.

CAVES AND SINKS.

Throughout the surface extent of the cavernous limestone of the Upper Burlington, through the central and western portions of the area, there are found a large number of caves, some of which are very remarkable and deserve more than passing notice.

The chief cavern of this formation is Percy cave, seven miles northwest of Springfield (Tp. 30 N., R. XXII W., Sec. 33),

formerly and more widely known as Knox cave. Its location is at the head of a deep, narrow gorge that extends a little less than one-quarter of a mile south from Sac river. This gorge, no doubt, represents a former portion of the cave the roof of which, having fallen in, has filled up its former outlet. Since its discovery, 1866, this cave has been carefully protected from vandalism, and is more perfectly preserved than the majority of such places. The present opening has been partially walled up, and is guarded by an ordinary door. Upon entering, after passing over huge blocks that have fallen from the roof, there appear numberless immense pilasters. Then going over a small hill of fallen debris a narrow gorge is reached, where the roof is exquisitely beautiful from innumerable, slender stalactites, many of which are formed around the penetrating roots of trees that are growing on the surface of the ground above the cave. Climbing up a steep incline at the further end of this gorge, a large chamber is soon reached which is about 30 feet high by 75 feet wide, from which opens a smaller side-chamber which has been explored only a short distance. Penetrating more deeply into the cave, the edge of a deep gorge is reached, and suddenly a descent is made to a small bridge over a wet-weather stream which crosses the gorge at right angles. A number of blind crawfish have been obtained from this rivulet. Ascending the steps cut into the steep bank beyond the bridge, the end of the accessible portion of the cave is soon reached. Here the roof very rapidly inclines toward the floor and one is compelled to stoop in order to pass to the large and beautiful spring at the end of the cave. Although hardly one-half mile in length, and with chambers of no very great size, this cave is still one of the most beautiful in the United States. The constant variety met with in the display of stalactites which range from sparkling, creamy white to earthy brown in color, the splendid fluted pilasters, some of large size, and the beautiful rosettes of stalactitic origin in the roof, all contribute to form a series of scenes which, in the wierd intensity of electric lights, make a profound impression upon the observer. This cave and the adjoining grounds have recently been purchased

and such improvement is constantly being made to the naturally picturesque surroundings as will tend in time to make this one of the most attractive summer resorts in the state. The beautiful Amphitheater spring, described in another place, is in the immediate vicinity of this cave; and the views up and down the Sac river are exceptionally fine and pleasing.

Fisher cave, near Galloway, is another interesting point. It opens in a low bluff on the east side of the valley through which the Chadwich branch of the St. Louis and San Francisco railroad passes. It is about 8 feet high and 30 feet wide at its mouth, and enters the bluff in a northeasterly course. A stream of pure cold water issues from its mouth. About 300 feet from the entrance the cave attains a width of about 60 feet and a height of about 25 feet. A short distance further a spring rises from the eastern side, beyond which there is a waterfall of several feet, and to this point the explorer is conveyed in a boat. The cave forks here to the north and east. It has been explored for several hundred feet beyond the first waterfall. A second fall, of about six feet, is found at the end of the east branch, and beautiful stalactites are everywhere present. The fine spring which has its outlet through this cave was taken advantage of by the settlers as early as 1840. Recently boats have been provided for the stream, pavilions have been built, the grounds around the cave have been converted into a beautiful park, and the place is rapidly becoming a summer resort.

The Smallen cave, formerly called Fountain cave (Tp. 27 N., R. XXI W., Sec. 12, Sw. qr.) is on a small branch of the Finley river. It has two openings nearly a mile apart. Through the lower orifice a stream of considerable size flows and forms a little creek. The mouth of this cave is about 70 feet high and nearly 100 feet broad, rapidly narrowing a few hundred feet within.

Schoolcraft, in his journal "Scenes and Adventures in the Semi-Alpine Regions of the Ozark Mountains in Missouri" (p. 107) graphically describes his visit to this cave in 1818. He says:

"I observed a small stream of pure water coming in on the north side, which issued through an opening in the hills; and as this ran in the general direction we were pursuing, the guide led up to it. We were soon enclosed in a lateral valley, with high corresponding hills, as if, in remote ages, they had been united. Very soon it became evident that this defile was closed across and in front of us. As we came near this barrier, it was found that it blocked up the whole valley, with the exception of the mouth of a gigantic cave. The great width and height of this cave, and its precipitous face, gave it very much the appearance of some ruinous arch, out of proportion. It stretched from hill to hill. The limpid brook that we had been following ran from its mouth. On entering it, the first feeling was of being 'in a large place.' There was no measure for the eye to compute height or width. We seemed suddenly to be beholding some secret of the great works of nature, which had been hid from the foundation of the world. The impulse, on these occasions, is to shout. I called it Winoca. On advancing, we beheld an immense natural vase filled with pure water. This vase was formed from concretions of carbonate of lime, of the nature of stalagmite, or rather, of stalactite. It was greyish-white and translucent, filling the entire breadth of the cave. But, what was still more imposing, another vase, of similar construction, was formed on the next ascending plateau of the floor of the cave. The water flowed over the lips of this vase into the one below. The calcareous deposit seems to have commenced at the surface of the water, which continually flowing over the rims of each vase increases the deposit.

"The height of the lower vase is about five feet, which is inferable by our standing by it, and looking over the rim into the limpid basin. The rim is about two and a half inches thick. Etruscan artists could not have formed a more singular set of capacious vases.

"The stream of water that supplied these curious tanks, rushes with velocity from the upper part of the cavern. The bottom of the cave is strewed with small round calcareous

Smallen's Cave, near Ozark.

stream of water,
ce that is utilized for
g. This park is the most

popular resort for the citizens of Springfield, and its natural beauties have been greatly enhanced by judicious improvements.

Of the numerous smaller caves which abound throughout the district, only a few will be noted: The Lapham caves and sinks in Cass township (Tp. 30 N., R. XXIII W., Sec. 23); the cave from which Jones spring issues (Tp. 29 N., R. XXI W., Sec. 27); Woody cave, north of Ozark, in Christian county (Tp. 27 N., R. XX W., Sec. 6); the Little Yosemite (Tp. 29 N., R. XXI W., Sec. 28); Wild Cat cave, near Boiling spring (Tp. 23 N., R. XXI W., Sec. 15); the cave in the bluff at the Peirson Creek mines; the Robberson cave (Tp. 30 N., R. XXI W., Sec. 17, E. ½ of Ne. qr.); the McGuire cave on the Brighton-Pleasant Hope road (Tp. 32 N., R. XXII W., Sec. 34); and another one north of Pleasant Hope on Potomac branch. Several interesting caves are found on the south side of the James river east of Patterson spring, on the Yarborough farm.

Among the numerous sinks that are found in this area, the most interesting, and by far the largest, is the Panther den, situated where the Benton branch of Panther creek leaves Benton township (Tp. 28 N., R. XIX W., Sec. 3). Though this remarkable phenomenon is so often mentioned in histories and reports on this part of the state, there seems to have been no attempt to explain what a little study will make clear in regard to its origin. Approaching this sink, or "mysterious lake," from the east, one passes from Burlington limestone, in section 2, on a moderately abrupt slope, probably over an unexposed bed of Chouteau and Hannibal shales which are covered with the indestructible Lower Burlington chert. In the northeast quarter of the northwest quarter of section 2, two adjoining sinks are passed which are striking enough to notice, and which aid in explaining the origin of the "Devil's Den." Only a very narrow ridge separates these two sinks, and a line drawn through both of them gives a course N. 20 degrees W. They are each about 25 to 30 feet deep, and the larger is perhaps, 150 feet long, by 80 feet wide. The significance of their course, the position of

the sinks on the summit of the ridge, and their proximity to the neighboring mining camps, will be emphasized in another section of this report. A number of very large trees grow upright in these sinks, and some stumps and decaying trees indicate the path of a former tornado. The Burlington debris covers the steep sides, so that no outcrops can be studied. Next, on the way to the great sink, about 20 feet of Devonian limestone is passed over, along a gentle slope downward. This descent continues over an 18-foot slope of First Magnesian, and then First sandstone, then to a foot-hill overlooking, and about 60 feet above, the north side of the Benton branch of Panther creek, the stream flowing on the other (or western) side of the valley, which is, perhaps, a third of a mile wide at this point. Leaving the wooded ridge, the explorer abruptly finds himself at the edge of a gulf or chasm surrounded by overhanging ledges of Saccharoidal sandstone, and 80 feet below lies a deep, dark pool of water. This chasm is blunt at the south end, but runs off into a narrow fissure at the north end. It is somewhat pear-shaped. Roughly measured, it is 150 feet long by 80 feet wide. The only point where it can be entered is through the crevice at the north end. Climbing down on the rough ledges for about 40 feet, an abrupt shelf is reached, where an old ladder has been placed. Descending this ladder to a sloping talus, the water's edge can be reached. This water rises and falls according to the rainfall. When first visited, the water was moderately low, and with careful work, one might creep around on the eastern edge so as to get a good view of the block-like ledges of First sandstone which overhang the sink all around with a thickness of about 15 feet, casting a dark and gloomy shadow over all below. The water in the bottom was quite muddy, although it did not seem stagnant. When visited the second time, the water was 15 or 20 feet higher, and a careful examination of the surrounding walls gave evidence that it must reach, in very wet times, nearly to the top of the second soft layer. In the south end were noticed two decided fissures which were found to

run N. 15 degrees W. Old inhabitants state that logs thrown into the water disappear, and are carried away through some underground passage. The crevices were noted on the north end, the eastern one being the fissure through which descent into the "gulf" is possible, and the western one was well outlined in the wall to the northwest. These crevices were 20 feet apart, slightly converging toward the bottom and south end. Indications of a cross crevice were noted in the northwestern corner. Measurements gave the depth of the water on the west side as 62 feet. On the south side opposite the east fissure 70 feet was obtained.

The evidence, then, all goes to prove that this "Panther's Den" is really an immense sink, similar in every respect to the great "Gulf" in Howell county, and it also has great similarity to the two "gulfs" or sinks, one of which opens by a natural bridge near the Gunter spring and lake, in Camden county.

The Gunter spring flows out from the base of a precipitous bluff, bordering on the edge of a narrow gorge extending down to the Niangua river. There is evidence here that this immense spring issued further up the gorge, but, by an undermining and caving in of the roof of its old cave channel, an immense sink was formed, which opens toward the main gorge under a beautiful natural bridge, which escaped the general falling in.

The "Panther's Den" or "Gulf" may be accounted for by an undermining and washing out of some of the softer strata of the Second Magnesian by an underground stream. This was facilitated by the fact that several crevices extending through the sink formed natural water-ways. The situation of the "Gulf," at the junction of at least three crevices, renders the conditions eminently favorable for such an underwashing and subsequent sinking. At the south end the fissures, as exposed in the wall, converge slightly towards each other as they go down, leaving a wedge-shaped portion of rock as a kind of keystone which preserved that end.

No very large springs are found, however, south of this point, though there are several small ones that may, and probably do have their source in this reservoir. One, the Sherman spring, seems to issue from a crevice that is almost, if not exactly, on the range line with the fissure in the "Gulf." These fissures are continuous with the mines half a mile to the north.

Mr. Clay Derrick, who lives southwest of Elkland, describes a very remarkable sink in the Second Magnesian (Tp. 32 N., R. XIX W., Sec. 35, Ne. ¼ of Sw. qr.) He states that it covers an acre in extent and is 50 feet deep, with steep sides. During heavy rains, the outlet is not sufficient to carry off the drainage, and the sink rapidly fills, forming a pond. Air bubbles up through the water with considerable noise as it settles in its underground channel.

Grand prairie contains a large number of remarkable sink-holes, arranged more or less in groups and having regular trends, which undoubtedly mark crevices and underground streams. Some of the most noteworthy groups exist about a mile southeast of Brookline in the vicinity of the mines; also about a mile south of Dorchester in the Haseltine pasture, and in Tp. 29 N., R. XXII W., Sec. 6, not far from the railroad section house. On the Crenshaw farm (Tp. 28 N., R. XXII W., Secs. 3 and 10), is a series of very interesting sink-holes. Many others might be mentioned, especially those in the southeast part of Tp. 29 N., R. XXIII W. The sink-holes on the prairie uplands are frequently taken advantage of by the farmers for making storage ponds for watering stock. The smaller streams in the upper Burlington limestone frequently disappear, and seem to find underground channels for considerable distances before they again appear. Wilson creek loses itself in this way in several places, especially in Tp. 28 N., R. XXII W., Sec. 18, Nw. ¼ of Ne. qr. The south fork of Dry Sac at one point also sinks for some distance in Tp. 30 N., R. XXI W., Sec. 36.

The consideration of caves and sinks throws much light on the origin of valleys, especially the deep gorges that cut into the large ridges. All the different stages in the evolution of the valley may readily be made out in the vicinity of the

caves and sinks. The percolating waters find an easy pathway through fissures or crevices, and gradually dissolve the rock and wash out underground channels and cavernous passages. In places the roofs of these passages give way and thus form larger reservoirs for the accumulation of surface waters. With the greater volume of water the undermining is increased and a series of sinks is formed which become continuous or separated by natural bridges. As these barriers finally give way, the result is a deep gorge in the bottom of which flows the stream. In some instances, as Percy cave, the valley is formed by gradual retrocession. Here the cave formerly had its mouth near the Sac, but the gradual caving of the roof due to the undermining of the waters, has formed a valley that reaches back to the present mouth of the cave, nearly one-fourth of a mile from its original opening.

SOILS.

The soils of Greene county have been formed in one of two ways: (1) In place, from decomposition of the rock beneath, as over the prairie uplands, hills and bluffs, and (2) as the result of erosion, the alluvium in the valleys supplementing the soils formed by the first method. There are no glacial deposits, the area being too far beyond the morainic border.

The value of a soil depends upon its chemical composition, porosity and degree of dampness. As the soils of this area are mostly derived in place, from the rocks beneath, the nature of the rocks with the addition of decaying organic matter determine essentially the character of the soils. In lime stone regions the soil is calcareous, in the uplands as well as in the bottom lands, where the drainage is all derived from the same formation. Where erosion in the valleys has cut through several formations, there is a mixture of the constituents of those formations which have been brought down by erosive action. Toward the mouths of the rivers the valleys become broader, the mixture greater, and the deposits finer, the coarser materials having been dropped as soon as the waters

became more quiet. In sandstone regions the soil is sandy, unless mixed with the decomposed materials of other beds. A sandy soil is too porous and light for the best crops, unless the rainfall is light and frequent. The water being quickly carried away from a sandy soil must be often renewed to keep vegetation vigorous. If there is too much clay the water is retained, and in wet seasons makes the soil too damp, while in periods of drought the earth bakes and forms a material which prevents the growth of the tender roots of plants and makes an impervious stratum which hinders the evaporation of subterranean waters. The proper mixture of calcareous (lime), silicious (sand), and argillaceous (clay) elements with organic matter and a right amount of moisture are desired. The variations in these mixtures are innumerable, and it rarely happens that a soil is found wholly unadapted to cultivation.

The various soils of Greene county are due to the differences in the composition of the geological formations from which they are derived. The sandstones of the Carboniferous give rise to soils that are fairly productive. There is in them usually a sufficient amount of iron and argillaceous material derived from the cementing matter to modify, to a degree, their great porosity, and thus enable them to be rated as second class soils. Where these elements have been largely washed out and the sand alone left, the extreme conditions of porosity are presented.

The upper Burlington furnishes the best soils in the area. The purity of the limestone and its great porosity and thickness together with the abundance of soft chert and carbonate of iron, give by decomposition all the constituents of a strong, and sufficiently porous, rich soil. Detritus from former beds of sandstone above also aid in contributing valuable residual material. From the decomposition of the beds of this limestone and chert is formed a highly ferruginous deposit of clay called geest, mixed with broken and decomposing chert, the latter generally giving the porosity to this clayey soil, especially where the shattering and fissuring of this formation has taken place through underground drainage. Where this is not the case the barren post-oak flats occur. One not

familiar with the soil of the upper Burlington formation is surprised at its productiveness, as the unfavorable appearance of the red clay so freely mixed with broken chert does not seem to indicate the great fertility of a soil that is not only rich but lasting.

The lower Burlington limestone presents, in the fertility of its soil, a marked contrast to that of the upper Burlington. Both formations are made up of alternating beds of chert and limestone, but their resulting soils are widely different. In both, the heavy deposits of chert are in the upper part of the formations; but in the lower Burlington, both the chert and limestone are extremely hard and compact, while in the upper Burlington, the reverse is the case. The decomposition of the lower Burlington, if in the upper portions, gives heavy layers of broken chert with very little admixture of soil, except that obtained from the decomposition of superincumbent beds. The flinty, cherty slopes of the southeastern portion of the area, which are usually left to woodland, are good examples of soil derived from the upper layers of the lower Burlington beds. The decomposition of the lower limestone beds is slow and results in a much thinner and poorer soil than that of the upper Burlington. The abundance of thin, intercalated beds of chert also renders this soil very flinty, and the compactness and hardness of both limestone and flint make it more purely argillaceous, though lacking in the porosity necessary for a good soil.

The Kinderhook presents three beds from which soil may be derived, but they are all thin. The Hannibal sandstone and shale is much the thickest and most important member, the largest area being underlain by it. The soils from the Kinderhook are chiefly from this formation. These shales and sandstones are found mainly in the form of terraces and slopes along the valleys, or in patches along the crest of the Graydon-Northview monocline.

Alone, the soils from either the sandstone or shales are very unproductive, but when mixed with eroded material from the upper formations they are very fertile. Many of the post-oak flats along the high plateau on the crest of the Graydon-North-

view ridge are underlain by these shales, and are barren and desolate, with a cold, damp, clayey soil in wet weather, and a dry ashy soil in times of drought. They are sparsely clothed with coarse vegetation and stunted trees. Abrupt slopes are frequently covered with blocks of sandstone, and these blocks are frequently arranged in long lines of outcroppings along the hillsides.

The Devonian beds are too thin to form a soil with any distinctive characteristics, but by their decomposition they form an admixture which adds materially to the productiveness of the soils with which they are mingled.

The Silurian rocks are represented in this district by alternating beds of sandstone and limestones. The soils derived from the sandstones of this age somewhat resemble those from the sandstones of the Carboniferous, but they are far less productive, owing, no doubt, to the lack of cementing material which exists more abundantly in the latter formation. The rocks are softer and the soil more porous, which is also a detrimental feature. The limestones of this age are all highly magnesian, merging both above and below into highly silicious, cherty beds. These cherty beds form rugged and desolate regions with scanty soil and sparse vegetation. The limestone of the First Magnesian is, usually, scant in the greater part of the area and forms very little soil. Good examples of it may be seen in the barren First Magnesian glades which exist in patches along the crest of the Graydon-Northview monocline. The middle beds of the Second Magnesian and the calcareous beds of the Third Magnesian limestone form, where decomposed, a rich, black and productive soil.

FORESTRY.

The greater part of this district is well wooded, oak and hickory being the predominant varieties of trees. The country is well diversified with a mixture of prairie and timber which provides an abundance of farming lands with a good supply of building material, fuel and fencing. It is a mistaken idea that the supply of timber in this region is decreasing; on the

contrary it is largely increasing. Attention was first called to this fact by Mr. J. W. Blankinship who has given a great deal of study to the flora of the region. He learned from the testimony of old setlers that seventy years ago there was probably not one-half the timber in the country that there now is. Schoolcraft, in 1819, in speaking of the James river says: "The timber on its banks is abundant, a remark which cannot with justice be made of many parts of the adjacent country, and is remarkable for its size and its value, and nothing can exceed the vigor and verdure of vegetable nature on this beautiful and neglected stream. Prairies are also found within a mile of its western banks and extend toward the Grand Osage as far as the eye can reach, level as a graduated plain, and waving with tall grass, on which the elk, the buffalo and the deer feed in countless numbers." In those early days the timber covered only the bottom lands of the Sac and James rivers and the early inhabitants felt great solicitude lest it should be entirely destroyed. It has probably increased one-third within the last forty years.

Since the building of the Kansas City, Ft. Scott and Memphis railroad and the Chadwick and Bolivar branches of the St. Louis and San Francisco railroad, a number of timber industries have been developed and a large quantity of wood is shipped annually for fuel and building materials. The white, post and burr oaks are largely cut for railroad ties, fence posts and lumber, the greater part coming from Christian county, south of Greene. A remarkable example of the durability of post-oak where exposed to the weather is seen in the old Salem church, built in 1837, in Tp. 30 N., R. XXI W., Sec. 4. The corners of this log church rested upon split logs of post-oak the flat side laid on the ground. The logs at one of these corners still support the building, after a lapse of nearly sixty years.

The native supply of black walnut is virtually exhausted, and it is somewhat surprising that more attention is not paid to its cultivation, as it is easily propagated from the seed and there are many apparently worthless tracts in this area which

planted with walnuts would produce, in the long run, more profitable harvests than are reaped from the best of farming lands. A notable exception to the lack of black walnut culture is seen on the Crenshaw farm a few miles south of the city of Springfield, where a beautiful grove of young walnut trees line either side of a long avenue which leads from the main traveled road to the heart of the large and fertile farm.

Many of the cherty southern slopes of the Burlington could be profitably utilized for fruit farms and for the culture of the grapes. In the year 1890 the apple crop in Missouri realized a greater profit to the acre than the wheat crop.

A list of the native trees of the county is appended:

Red cedar, *Juniperus virginiana*, L. Rare.
Butternut, white walnut, *Juglans cincera*, L. Not uncommon on low grounds.
Black walnut, *Juglans nigra*, L. Scarce native, but being cultivated.
White-heart hickory, *Hicoria alba*, (L.) Britton.
Brown hickory, or pignut, *Hicoria glabra* (Mill.) Britton.
Thick shell-bark hickory, *Hicoria laciniosa* (Michx.) Sargent.
Small fruited hickory, *Hicoria microcarpa* (Milt.) Britton. Infrequent.
Bitternut, white hickory, *Hicoria minima* (Marsh) Britton.
Shell-bark hickory, *Hicoria ovata* (Mill) Britton.
Cottonwood, *Populus monilifera*, Ait.
American aspen, *Populus tremuloides*, Michx. Introduced
Marsh willow, *Salix humulis*, Marshall.
Black willow, *Salix nigra*, var. *wardi*, Bebb. Rare.
Ironwood, *Ostrya virginica*, Willd. Frequent.
Hazelnut, *Corylus americana*, Walt. Common.
White oak, *Quercus alba*, L. Common.
Shingle, or laurel oak, *Quercus imbricaria*, Michx.
Post oak, *Quercus minor* (Marsh) Sargent. Very common on "post-oak flats" and barrens.
Burr-oak, moss-cup, *Quercus macrocarpa*, Michx.
Chinquapin oak, *Quercus muhlenbergii*, Engelm.
Black jack oak, *Quercus nigra*, L. Very common.
Pin oak, swamp Spanish oak, *Quercus palustris*, Du Roi.
Prairie oak, *Quercus prinoides*, Willd.
Red oak, *Quercus rubra*, L. Common in rich woods.
Texas red oak, *Quercus texana*, Buckl. Frequent. J. W. B.
Black oak, *Quercus velutina*, Lam.
Wahoo, winged elm, *Ulmus alata*, Michx.
White, or American elm, *Ulmus americana*, L. In low woods.
Red, or slippery elm, *Ulmus pubescens*, Walt.
Hackberry, *Celtis occidentalis*, L. Not common.
Mulberry, *Morus rubra*, L. Common.
Osage orange, *Toxylon pomiferum*, Raf.
Tulip tree, *Liriodendron tulipifera*, L. Not rare along the Sac.
Pawpaw, *Asimina triloba*, (L) Dunal. Along the larger streams.

Common sassafras, *Sassafras sassafras*, (L.) Karst.
Spice wood, *Benzoin benzoin*, (L.) Coulter. Infrequent.
Sweet gum, *Liquidambar styraciflua*, L.
Sycamore, *Plantanus occidentalis*, L. Common along rivers.
American crab apple, *Pyrus coronaria*, L.
Crab apple, *Pyrus iowensis*, Bailey. Common.
Shadbush, June-berry, *Amelanchier canadensis*, (L.) Medic.
Red haw, *Crataegus corcinea*. L. Rare.
Black thorn, *Crataegus tomentosa*, L.
Cockspur thorn, *Crataegus crus-galli*, L. Common.
Wild or Canada plum, *Prunus americana*, Marsh. Common.
Chickasaw plum, *Prunus angustifolia*, Marsh.
Wild goose plum, *Prunus hortulana*, Bailey. Rare. J. W. B.
Wild black cherry, *Prunus serotina*, Ehrb. Common.
Choke cherry, *Prunus virginiana*, L.
Red bud, Judas tree, *Cercis canadensis*, L. Common on bluffs.
Honey locust, *Gleditschia triacanthos*, L. Rich bottoms, common.
Locust, *Robina pseudacacia*, L.
Prickly ash, *Xanthoxylum americanum*, Mill. Frequent. J. W. B.
Black sumach, *Rhus copallina*, L. Common. J. W. B.
Hoptree, *Stelea trifolia*. L. Rare. J. W B.
White sumach, *Rhus glabra*, L. Common.
Staghorn sumach, *Rhus hirta*, L.
Strawberry bush, *Enonymus atropurpurens*, Jacq. Infrequent. J. W. B.
Bladdernut, *Staphylia trifoliata*, L. Rare.
Box elder, *Acer negundo*, L. Along streams, rare.
Red maple *Acer rubrum*, L. In low bottoms.
White, or silver, maple, *Acer saccharinum*, L. Frequent.
Sugar maple, *Acer saccharum*, L. Not uncommon.
Ohio buckeye, *Æsculus glabra*, Willd. Common.
Buckthorn, *Rhamnus lanceolatus*, Pursh. Frequent.
Basswood, *Tilia americana*, L. Along larger streams.
Kinnikinnick, *Cornus amomum*, Mill.
Dogwood, *Cornus canidissima*, Marsh.
Flowering dogwood, *Cornus florida*, L. Not common.
Persimmon, *Diospyros virginiana*, L. Common.
White ash, *Fraxinus americana* (L.) Common.
Green ash, *Fraxinus lanceolata*, Brock. Common. (J. W. B.)
Blue ash, *Fraxinus quadrangulata*, Michx.
Catalpa, *Catalpa catalpa*, (L.) Harst.
Button bush, *Cephalanthus occidentalis*, L. Common.
Elder, *Sambucus canadensis*, L. Common.
Sheep berry, *Viburum lentago*, L. In rich woods.
Black haw, *Viburum prunifolium*, L. Common.

STRATIGRAPHY.

GENERAL RELATIONS OF FORMATIONS.

The rocks of this district consist of (1) a series of more or less evenly and regularly bedded deposits composed largely of white limestones with some shale; and (2) a sequence of

heavily bedded or massive buff magnesian limestone. The former are almost entirely lower Carboniferous rocks which bear considerable chert and which are overlain, in isolated places, by beds of sandstones. Farther northwest, these limestones form the great basement upon which the coal measures of the state rests; but Greene county lies beyond the coal measure margin, and consequently extensive deposits of mineral fuel are not to be expected. The second series, or the magnesian limestones or dolomites, belong to the basal portion of the Silurian. They are chiefly exposed in the river valleys on the northern, southern and eastern borders of the district where they have been brought to the surface through the vigorous erosion of the streams. Between the two formations there is a wide interval covering the most of the Silurian and Devonian, the latter being probably represented in this region by a few thin beds of limestones, sandstones and shales, though well developed in the eastern part of the state.

The general scheme and classification of the geological formations included within the limits of the district are shown in the accompanying table:

Table of Geological Formations.

System.	Series.	Stage.	Formations.
Carboniferous.	Des Moines.	Cherokee.	Graydon sandstone.
	Mississippian.	Augusta.	Upper Burlington limestone. Lower Burlington limestone.
		Kinderhook.	Chouteau limestone. Hannibal shales. Louisiana limestone.
Devonian.		Hamilton.	Phelps sandstone. Sac limestone. King limestone. Black shale.
Silurian.	Ozark.		First Magnesian limestone. First sandstone. Second Magnesian limestone. Second sandstone. Third Magnesian limestone.

GEOLOGICAL FORMATIONS.

SILURIAN.

The oldest rocks exposed at the surface in the area are the Magnesian limestones which have been referred to the Ozark series. In the extreme northeastern part there has been recognized on the Pomme de Terre river the following section:

		FEET.
5.	Limestone magnesian (First)	50
4.	Sandstone (First)	20
3.	Limestone magnesian (Second)	10
2.	Sandstone (Second)	15
1.	Limestone, magnesian (Third), exposed	10

The exact relation of these beds to similarly named successions in other parts of the state is not yet definitely known. For this reason, without referring to geological age, they will be referred to as First, Second and Third limestones and sandstones. In these beds but few fossils have, as yet, been found, and these are very imperfectly preserved and are confined to the upper part. The rocks comprising the series are usually heavily bedded. In many places they are highly silicious, and vary in composition and texture from highly calcareous cherts to hard, translucent quartzite. The former are frequently oolitic, the chert masses being usually nodular and concretionary, with mammalary and botryoidal surfaces which are covered with drusy quartz. The limestones are all dolomites and vary from thin or heavy bedded, highly silicious limerocks, to very compact, fine-grained dolomites ("cotton rock"). In this area, and in the adjacent territory, a decided and almost regular increase in the percentage of silica and the tendency toward the quartzite structure is noted in descending, geologically, toward the granite. The upper beds are more magnesian, and softer in texture. On account of the almost total absence of fossils, the determination of horizons must largely depend upon position and lithological characteristics.

Third Magnesian Limestone. This is the lowest formation exposed within the limits of this area. While it occurs only at one point in the northeastern portion of Greene county, it

becomes, just beyond, the most prominent formation. The only ascertained outcrop is at the ford on the Fair Grove and Elkland road, where the Pleasant Hope anticline brings it to the surface in the bed of the Pomme de Terre. About twelve feet are exposed from the bed of the stream to the bottom of the Second sandstone above. The outcrop is considerably higher on the east side of the stream where a quarry has been opened. The upper beds of this formation on the west side of the river are exposed in a little gorge formed by the water from a small spring, and the surface, where visible, is covered by large and small "pot-holes." The upper six feet form a rather coarse-grained, light gray, magnesian limestone, distinctly marked by thin layers of alternating harder gray and softer yellow material. The rock is frequently somewhat blotched with a thin, whitish efflorescence. The lower part of the exposure is somewhat shaly, seamed and fissured, and containes much chert which is often oolitic in structure. The limestone is magnesian, very silicious, hard and compact, pinkish drab in color, and contains minute oval cavities and crystals of limpid calcite. On the east side of the Pomme de Terre, the Adams quarry has been opened in a beautiful white, fine-grained "cotton rock" of this formation. No fossils have been found in this horizon.

Second Sandstone. Of the three points at which this sandstone is known to outcrop, one is in the bed of the Pomme de Terre, where the Third limestone already mentioned occurs. A section of about 20 feet is exposed, the upper three-fourths being highly ferruginous, heavily bedded, generally soft and friable, and easily broken down and eroded. It is somewhat variable in structure, but is usually coarse-grained with the stratification lines frequently visible. The grains themselves vary in texture, shape and size; some are limpid quartz, some stained ferruginous quartz, while throughout the whole mass are found occasional milky white grains. The granules are all more or less irregular in shape, in which respect they differ from the grains of the first sandstone. The amount of cementing material, which is calcareous, is considerable, thus giving

another point of difference between the rock under discussion and the First sandstone. The lower layers of the bed are coarse-grained, distorted, of great irregularity of composition, and they frequently become cherty. They weather into strangely varying forms, and the grains are somewhat brecciated from the presence of very small angular particles of chert. Frequently the ferruginous matter is so abundant as to segregate into minute particles, which form dark blotches on the surface of the rock.

Crossing the Pomme de Terre, on the Elkland road, a small branch that comes in from the north is followed for a short distance. On the east side of this branch there is a bluff of the Second sandstone with a thickness of 35 to 40 feet. The face of the bluff shows false bedding and ripple marks. In the extreme northeastern corner of this district (Tp. 32 N., R. XV W., Sec 19) at the headwaters of one of the western branches of the Niangua, this sandstone outcrops with a thickness of about 20 feet. The third and last point at which this sandstone outcrops is in the extreme edge of the area, in the middle of the east line of section 3 (Tp. 31 N., R. XIX W.), on Gibbon branch. From this point, down the branch to the Niangua, are fine bluffs of this rock, but they lie outside of the area herein described. Mr. Woods, who has sunk a large number of wells in this region, says that where he has passed through this rock it rarely exceeds 20 feet in thickness. In Tp. 31 N., R. XIX W., Sec. 9, Nw. ¼ of Sw. qr., in a well sunk for Mrs. McNab to the depth of 92 feet, the last 20 feet were in sandstone without going through it. This formation has probably, a uniform thickness, as is indicated by the slight difference in the points before referred to. The Springfield and the Lebanon drill-well sections give a thickness of 32 feet in the latter, the former stopping at 30 feet in this sandstone.

With the exception of some obscure fucoid markings found in the upper beds of this sandstone, in Tp. 31 N., R. XX W. Sec. 15, Nw. ¼ of Sw. qr., no fossils have been found in this horizon.

Second Magnesian Limestone. With the exception of the northeastern part of the area, this formation has a very limited distribution in the territory under consideration, and at no point has it been possible to obtain a complete section. The upper or lower beds outcrop in many sections, but no comprehensive outline of the middle beds of the formation as a whole can be given. To the north, and particularly to the east and south of the district, the Second Magnesian thickens greatly, reaching, at Lebanon, in Laclede county, a thickness of over 400 feet, as given in the carefully prepared section of the "magnetic well." To the southeast it has a thickness of nearly 500 feet. At the power-house of the Metropolitan Electric railway, at Springfield, a carefully kept record of the drill-well gives but 90 feet for this formation, although another well about a mile north of the first-named gives, with some doubt, about 130 feet. While the formation is comparatively thin in the vicinity of Springfield, it thickens rapidly to the east and south. Whenever exposed, this rock is a rather soft (when freshly broken), fine-grained, compact, grayish-white rather thin-bedded, dolomitic limestone. The upper beds are usually, though not always, highly silicious, and in weathering exhibit the jagged honeycombed peaks or monument-like masses similar to, though on a far larger scale than, those of the First Magnesian limestones. The lower beds are also almost always more silicious and pitted with geode-like cavities, or honeycombed by weathering, leaving silicious skeletons in strangely contorted forms, standing up in places in jagged peaks two or three feet high and so close together as to make traveling among them very difficult. Sometimes they merge into the Second sandstone through cavernous, cherty and concretionary beds. One or two layers of thin sandstone are frequently intercalated in the middle beds, and usually, also, a variegated blue and white shale, called, in the mining districts, the "soapstone" layer. In numerous drill-well sections in the northeast, clay openings several feet in width, often forming underground waterways, are of frequent occurrence.

In the southeastern quarter of the area, exposures are confined almost wholly to Taylor township (Tp. 29 N., R. XIX W.) and only a small portion of the upper beds are seen. In the walls of the "Devil's Den," east of Henderson, in Webster county, the upper layer of this formation is about 15 feet thick, bluish in color, ferruginous, heavy-bedded, cherty and silicious, finely sub-crystalline and occasionally contains small cavities lined with calcite. At other points in the immediate neighborhood, a tendency is noted in the abundance of the silica toward a transition to the cherty, honeycombed layers so characteristic in the north. The next six feet underneath are a buff-colored, soft, shaly, "cotton rock," weathering so as to leave the upper layer as an overhanging ledge and breaking with an irregular, columnar fracture, with stratification marks plainly visible. The next 20 feet are crumpled, porous, dolomitic limestone. The succeeding four feet below are soft, magnesian limerock, weathering out and leaving the layer above overhanging. Then follows twenty feet of heavy-bedded stratum, crumpled in places.

In passing northward from the last-mentioned point, the amount of silica in the upper layer steadily increases, until along the east bluff of the Pomme de Terre at the western edge of Webster county, especially in Tp. 31 N., R. XIX W., Sec. 31, there are honeycombed beds. In places these rocks present an irregular, jagged, cherty escarpment, while at other points massive blocks are tumbled over the surface in an extraordinary manner. The resemblance to the upper beds of the First Magnesian limestone is very striking, the chief difference being that these Second Magnesian blocks are larger, more irregularly distributed, and that they are on bluffs and slopes rather than in glades. They are also more cherty, especially the lower layers resting upon the Second sandstone.

In striking contrast to the grotesque masses of cherty limestone, which form the barren sections in the edge of Webster county, there is found on the west side of Pomme de Terre, the fine farming lands of Greene county. In the latter county, the long, gentle slope towards the Pomme de Terre seems to

be due to the breaking down of the numerous alternating Second Magnesian layers of unequal thickness and texture which are beneath the upper cherty beds. These decomposing beds form a warm, rich, grayish soil, not very well adapted, however, to resist drought. The curious weathering of this formation is also seen at various points farther north, along the east side of the Pomme de Terre, and on the upper part of King branch in Tp. 31 N., R. XXII W., Secs. 29 and 35, where there is a small castellated bluff, as well as in Tp. 31 N., R. XXI W., Sec. 2, Ne. qr., and extending through Tp. 32 N., R. XXI W., Secs. 35 and 26.

On the Cowden place, near Fair Grove (Tp. 31 N., R. XX W., Sec. 29, Se. qr.), a shaft was put down to a depth of 46 feet then a drill-hole was sunk 110 feet farther, giving a total of 156 feet of Second Magnesian limestone. At a depth of 35 feet, a finely banded limestone was encountered, the thin, irregular green and white zones presenting a handsome appearance. At 100 feet from the surface, a bed of soft, white rock, 15 feet thick, which resembled "soapstone," was passed through. This soft layer is quite common in the lower middle beds of the Second Magnesian in Christian county. Two miles directly west of Fair Grove, on the west side of Little Pomme de Terre, 25 feet of river-bed conglomerate are found overlying the Second Magnesian limestone. The upper layers of the latter, immediately underlying the conglomerate, are made of a very fine-grained, hard, light gray, heavily bedded "cotton rock" having a thickness of about 10 feet. The next three or four feet are thin-bedded, shaley flint, showing indistinct bedding planes, and a bluish white color. The lower six feet are irregular masses of thinly bedded magnesian limestone, somewhat contorted and, in places, silicious and flinty. The last layers extend below the bed of the stream. About one mile northeast of this section (Tp. 31 N., R. XXI W., Sec. 25, Se. qr.), in a shaft at a point about 15 feet above the bed of the Pomme de Terre, a depth of 135 feet was reached without passing entirely through the Second Magnesian limestone.

Along the Dry Sac, near a school house (Tp. 31 N., R. XXI W., Sec. 23), the upper beds of the Second Magnesian outcrop in the stream bed, and are made up of a white, highly silicious limestone which gives off a fetid odor when struck. Good outcroppings also occur in the draws running into King branch near its head; in the low mural bluffs which run for some distance up the stream, where the faulting on Presley hill raises this rock to the surface; along Asher creek, near the Polk county line; and along the western bluff of the Sac, by Johnson ford, in Tp. 32 N., R. XXIII W., Sec. 29. At the last locality the upper layers are highly silicious and shaly, and are overlain by the First sandstone. Then come heavier beds of a beautiful grayish limestone filled with mottled irregular cavites containing a soft, whitish material. South of the water tank, on the Bolivar branch of the St. Louis and San Francisco railroad, a small outcropping of Second Magnesian occurs in a shallow cut. One of the most striking exposures of the Second Magnesian in the area is a beautiful bluff on the west side of the Sac river on the Matherly place (Tp. 31 N., R. XXIII W., Sec. 24). It is a vertical wall of heavily bedded limestone about 500 feet long and 100 feet high, having a course a little north of west. It was evidently on the north bank of an old channel of the Sac. The upper portion is a hard, honeycombed, silicious layer, but the lower is softer and has been greatly eroded by the stream, so that there is now left, in places, an overhanging ledge which is sometimes 15 to 20 feet wide. From the constant drip of the water down its surface a peculiar bluish drab deposit is formed. Several curved, round caves run into the bluff. These are three to four feet wide and about as high, are beautifully rounded and arched, and mark former underground waterways. A number of prehistoric mounds built of flat stones occupy prominent places on the summit.

Where erosion has not strongly cut into this formation, a very beautiful rolling upland, with, usually, rich and fertile soil is found. An exception to this occurs along the western border of Webster county, in the northeastern portion of the area. In this region, the eroded and weathered upper layers

give to the country a grotesque, rugged and desolate aspect that must be seen to be appreciated. Where the streams cut through deeply in this horizon, beautiful bluff scenery is found, which differs from all other bluff formations in this area in being rarely precipitious, the irregularity in the texture of the beds resulting in the formation of benches and slopes, rather than sharp precipices.

No fossils of any kind are found within the area in this horizon. To the south, in Christian county, some imperfect specimens of Straparollus have been collected, and to the east a few shells have been taken in a railroad cut near Mansfield. North of the district limits and east of Bolivar a number of fossils have been obtained. As an ore horizon this formation is one of some importance. Considerable lead has been taken out of the mines along Panther creek and to the south in Christian county. Various attempts have been made to mine along the branches of Pomme de Terre and Sims but with indifferent success. These localities will be mentioned again in another connection. Many of the beds of this formation could be utilized for building purposes as well as for the manufacture of lime.

First Sandstone. This sandstone is mainly confined to the northeastern portion of the area though it also outcrops along the James river. It has a maximum thickness of 45 feet but varies greatly within short distances. It is a very durable rock, standing out prominently and forming benches and overhanging ledges in the bluffs of streams. While it is generally friable, it possesses, to a high degree, the power to resist the elements. In color it varies from a pure white to a yellowish brown or red. This coloration is due wholly to the presence of iron which seems to have penetrated the cementing material without in the least affecting the grains. The latter are almost always limpid quartz. The cementing material, so far as it has been possible to ascertain, consists of lime carbonate, an extremely small amount of which appears to hold the rock together. In the east and southeast the upper beds are cherty and occasionally fossiliferous. The chert is white, chalcedonic,

somewhat fragmental in structure, and merges more or less insensibly into the coarse-grained and usually light colored layers. The middle and lower beds here are harder, more compact and much darker in color. Frequently they become very much indurated almost resembling quartzite. Towards the north and east, where the beds thin out, the exposed surfaces are covered with abundant ripple marks. This is so in other places also, especially along the Morrisville road and particularly through Birdeye hollow (Tp. 31 N., R. XXII W., Sec. 20). In the last-mentioned locality the surface of eroded slabs is covered with peculiar fucoid-like markings, the ridges forming irregular rhomboidal patches or net-like meshes. These ridges are usually elevated from one-fourth to two-thirds of an inch above the surface of the rock and vary greatly in dimensions, sometimes enclosing areas two to four inches in breadth. The markings decidedly resemble a gigantic hydrodictyon, or water-net, one of the fresh water algae. An unusual variation of these occurs in the bed of Sims branch, just east of the Cash house (Tp. 31 N., R. XXI W., Sec. 32, Ne. ¼ of Se. qr.) but this peculiarity has never been noticed elsewhere. A thin layer of the sandstone outcrops in the bed of the creek and on it are peculiar, raised, slightly curved markings two to three inches long and half an inch thick and wide. These do not form meshes but run somewhat parallel with one another. They seem to be made up of obliquely overlapping joints and stand out prominently on the surface of the rocks. The slabs appear to break into more or less regular rectangular blocks.

In a well section at the power-house of the Metropolitan railway, at Springfield, there are 10 feet of this sandstone and it is very soft, white and friable. At the Phelps mines, five miles southeast of the same city, it appears to be not more than two feet thick. It forms the bed of the James river along nearly its entire course through Taylor township, frequently extending up the branches for some distance. In Dallas township, just east in Webster county, there are also many good exposures. Several sections give measurements of 20 to 30 feet of heavily beeded, coarse-grained sandstone. At the

"Devils Den" this formation shows its durable character by forming an overhanging wall around the softer and more easily decomposed layers of the Second Magnesian. North of Springfield, the first exposures are found at Presley hill on the Bolivar road. Here the block faults of the Graydon-Northview monocline elevate the first sandstone 200 feet above its proper position. Swallow* gives the following section at this point:

		FEET.
6.	Ferruginous sandstone	65
5.	Encrinital limestone	150
4.	Chouteau limestone	80
3.	Vermicular sandstone and shales	75
2.	Lithographic limestone	10
1.	Saccharoidal sandstone	12

He states: "On the road from Bolivar to Springfield 15 miles from the former town, in Tp. 31 N., R. XXII W., Sec. 16, I saw fine specimens of this rock (First sandstone) thus changed, and the whole more distinctly stratified than at any other place observed."

The following section is obtained at this point:

	FEET.
Lower Burlington chert slope	20
Chouteau limestone	5
Hannibal sandstone and shale	40
Sac limestone	10
Slope of First sandstone	10
Second Magnesian	25
Slope of First sandstone	25
Hannibal shale	15
Ridge of upper Burlington limestone	60
Hannibal slope	45
Devonian	15
First Magnesian (exposed to bed of Sac river)	8

The extraordinary position of the beds in the above section, from the top of Presley hill to the bed of the Sac, is due, as before stated, to the series of faults found at this point along the Graydon-Northview monocline. There is no deposit of ferruginous sandstone within several miles of this point, though a few scattered blocks are found in Tp. 31 N., R. XXII W., Sec. 34, and one of the branches of the old river bed passes within a few miles of the section. It is

*Geol. Sur. Missouri, I. and II. Ann. Repts., p. 118, 1855.

difficult to account for such a section by so careful an observer as Swallow. It is probable that he obtained the information from some observer who, possibly, might have mistaken the long tilted slope of the Saccharoidal sandstone for the Ferruginous sandstone. From this point westward there is a more or less continuous stretch of First sandstone, reaching an unusual thickness along Asher creek to the mouth of the Sac. On the Irby farm (Tp. 31 N., R. XXII W., Sec. 21, Nw. qr.) the sandstone outcrops in a number of places and dips strongly to the northeast. Immediately west of the Irby house, in the neighborhood road, are some fine exposures, covered with ripple marks. To the south, on the West Bend road, are some exposures in the bluff along Asher creek. At this point the sandstone attains the thickness of 45 feet, and the tumbled blocks are covered with ripple marks. For several miles southward along the creek, and especially near the Greene county line on the Cave Spring road, is probably the best location in the region to study the formation. The heavy beds form bluffs along the creeks and good sections are shown at many points, while surface exposures are abundant in the draws that cut through into the Asher. The sandstone thins out along the Big Sac in the northwestern part of the county. Just south of the water-tank near Graydon, on the Bolivar branch of the St. Louis and San Francisco railroad, is one of the most interesting outcroppings of the First sandstone that has been noted. Near the track for some little distance, the surface of the ground is thickly covered with great loose blocks from two to three feet in size. The sandstone can not have been more than six feet thick at this place. North and northwest of this place it covers the greater part of the region, except where the streams cut through into the Second Magnesian, and it varies from a few to 30 feet in thickness.

In a well on the Heniphan farm north of Springfield (Tp. 30 N., R. XXI W., Sec. 1, Ne. qr.) the First sandstone was reached at the depth of 30 feet. To the north and northwest of Presley hill the First sandstone is brought to the surface by the faulting and thinly covers small areas. Along King branch this

sandstone caps the bluffs and forms a bench running back a short distance to the First Magnesian, alternately becoming thin and thick in a peculiar manner.

Lead is found in vertical openings only sparingly in this formation, and in one sample a mass of sphalerite was imbedded. The formation is not recognized, however, as an ore horizon. There are few localities in the area in which this sandstone is pure enough for glass-making. For chimneys, foundation-walls and buildings, when sufficiently indurated, it is widely used by farmers and others. For plaster it is unusually good and will have a much wider use when transportation facilities are better. With the exception of the upper cherty beds this horizon is almost wholly destitute of fossils. Those found are chiefly casts of Murchisonia and Straparollus, and were obtained in Tp. 30 N., R. XIX W., Sec 26, Se. ¼ of Nw. qr. A few were also found in Tp. 31 N., R. XX W., Sec. 32, E. ½.

First Magnesian Limestone. This formation has a maximum thickness of 100 feet, but varies greatly at points not far distant from one another. The beds are much attenuated on the slopes of the Springfield divide, but reach a maximum thickness in the extreme southeastern portion of the district. Owing to the soft and easily decomposed nature of the beds immediately overlying them, it is almost impossible to find a sharp line of demarkation between the two. The upper beds, however, are almost invariably highly silicious. The silicious and calcareous material is mixed in a way that, in weathering, the harder silicious matter which is left gives the rock a honeycombed and pitted appearance which is very curious and striking.

Owing to the great variation in texture, erosion frequently leaves these beds in great blackened masses which cover the surface of the ground for long distances. In other places the softer matrix is removed and the cherty masses are smaller, nodular or lenticular in shape, varying in size from an inch to a foot or more in diameter, and covered with mammillary and botryoidal surfaces, occasionally drusy with quartz crystals. Locally these masses are called "niggerheads" or "cornshell-

ers." They either lie loosely on the exposed bed-rock, or are partially imbedded in the poor, ashy soil which forms many of the barren post-oak glades. Such a condition is well exhibited over the top of a broad ridge in Tp. 31 N., R. XX W., Sec. 21 Sw. qr., also in irregular patches from this place to Tp. 31 N., R. XXIII W., Sec. 9. At this last point is found a large glade with scant covering of dwarf grass and scrub post-oak. Besides the smaller masses there are numerous very much larger bowlders forming the nuclei for low, conical bosses, which are eight to fifteen feet in diameter at the base and about two feet high. These low hummocks have frequently been mistaken for Indian mounds but their origin is evident. From this extreme of variation in texture the rocks seem to merge into a more characteristic and widely distributed form toward the south and north where the beds still appear highly silicious, but the irregular cavities containing the less indurated matter are very much smaller, more uniform in size (one-eighth to one-quarter of an inch) and have a mottled or blotched appearance. This variety, upon weathering, leaves the surface covered with small, pit-like depressions.

To the east and south of this portion of the district the upper beds become more arenaceous and eventually merge into what the miners call the sand-flint layers—a very characteristic bed. It is a little less than two feet thick, although outside of the area it is reported to have a thickness of about twenty feet. The "sand-flint" is very hard and porous, and weathers in extremely rough, irregular rounded masses. Its cavities are lined with drusy quartz, and it is highly ferruginous. Below this, in the mining regions, there are from 10 to 30 feet of dolomitic limestone which is softer and less silicious. It is similar to "cotton rock," and varies from white to yellowish in color. To the east this bed contains intercalated layers of chert. It frequently merges into blue chalcedonic flint or chert, which overlies and graduates into the First sandstone below. At other points it becomes much more crystalline and silicious, honeycombed with small, irregular cavities which sparkle in the sunlight from myriads of minute quartz crystals.

It is frequently fossiliferous. In the mining regions, the unconformity between this horizon and the First sandstone is decided, and is represented by soft, thin, arenaceous beds. Where the crevice passes through this unconformity, what is called a "clay opening" is formed, which is usually rich in galena "chunk mineral." This is well illustrated in the Hornbeak mines, Tp. 27 N., R. XIX W., Sec. 2.

Above the upper honeycombed, flinty layer there is found, in some places in the southeastern portion of the area, and beyond, a thick bed of fine-grained, compact, magnesian limestone with delicate parallel lines representing bedding planes. In some respects this rock corresponds, lithologically, to the King limestone of the Devonian, but it is more probable that this deposit is either an upper bed of the First Magnesian, or that it belongs to an horizon between this and the Devonian. The shafts at the O'Haver mines (Tp. 27 N., XIX W., Sec. 35, Se. ¼ of Nw. qr.) pass through this limestone, the following being the general section:

		FEET.
7.	Limestone fine-grained, magnesian, "cotton rock".	25
6.	Flint, white.....	1½
5.	Flint, sandy.....	1½
4.	Limestone, spotted, "cotton rock".....	10
3.	Limestone, "spotted cap," heavy run of mineral.....	8
2.	Limestone, silicious, magnesian, dark reddish to yellow, hard and rather coarse-grained, with small cavities..... ..	20
1.	Sandstone, Sacchoroidal (exposed).....	2

No. 7 represents the doubtful bed referred to. Nos. 6 and 5 form the sand-flint layer of the miners, and are, without much doubt, the equivalent of the honeycombed chert layer which forms the upper bed of First Magnesian in the northern part of the district. Nos. 4 and 3 form one of the "spotted caps" of the miners, a grayish rock, mottled with irregular, whitish patches of slightly softer texture. A somewhat similar stratum is found in the Second Magnesian. The "spotted cap" layer is looked upon by the miners as covering richer deposits below. At the Hornbeak mines, Tp. 27 N., R. XIX W., Sec. 2, in the lower, silicious, porous layer of this horizon, some fine specimens of Straparollus occur. The shafts pass through thin intercalated

layers of bluish black, very hard, chalcedonic flint, in the beds above the sand-flint layer. At the mouth of the Finley, just outside of the area, the bed of the James river, for several miles extending up beyond Frazer's (Tp. 27 N., R. 22 W., Sec. 29) is composed of very thinly bedded, almost shaly layers of this formation. At the Phelps mines, already referred to, is the following section:

		FEET.
12.	Phelps sandstone	2
11.	Limestone, white, silicious, seamed with lines of whiter, calcareous material	14
10.	Flint, dark, porous	2
9.	Limestone, white, silicious	4
8.	Flint, spotted, coarsely laminated, containing some pyrites	4
7.	Limestone, silicious	1
6.	Flint, spotted, shaly	½
5.	Limestone, white silicious	1
4.	Flint, with small pea-shaped masses of black chert	1½
3.	Sandstone, with chert, compact, containing fine grains of sphalerite and pyrites	2
2.	Sandstone, white	½
1.	Shale, finely laminated, alternating layers of blue and white (exposed)	2

No 11 represents either the King limestone, or the doubtful horizon before referred to. Nos. 4 to 10 represent the First Magnesian. Nos. 2 and 3 belong to the First or Saccharoidal sandstone. No. 1 is the upper bed of the Second Magnesian.

On the northern side of the drainage crest, north of the Kite farm (Tp. 30 N., R. XIX W., Sec. 19, Sw. qr.), the following section was obtained from a well:

		FEET.
5.	Lithographic limestone	5
4.	Phelps sandstone	8
3.	Sac limestone and First Magnesian, probably 25 feet of the latter	40
2.	First sandstone	9
1.	Second Magnesian	18

On the west end of Newton mound (Tp. 31 N., R. XXI W., Sec. 1, Ne. qr.) the First Magnesian is exposed to a height of 70 feet. Ten feet of the upper portion of this represents the hard, flinty, honeycombed layer. Exposures also occur along the Sac in the northeastern corner of Robberson township, and in the southern part of Looney township, in Polk county. The upper layers, are marked by peculiar honeycombed weath-

ering. The lower layers, where exposed along Dry Sac, are reddish, silicious limestones, which emit a disagreeable odor when struck.

In only a few localities have fossils been found and these are mainly in the lowest silicious beds, rarely in the upper layers that are of doubtful position, and chiefly extra-limital. Some years ago, in the lower beds at the Phelps mines, some fine casts of Straparollus were found. An abundance of the casts of the same form, also of a small Murchisonia and a few corals, were obtained on the Kraemer farm (Tp. 27 N., R. XX W., Sec. 11, Se. qr.), on the McClelland place (Tp. 29 N., R. XIX W., Sec. 8), at the Johnson and Hornbeak mines, and on the Kite land, north of Strafford.

DEVONIAN.

A hiatus exists between the Carboniferous and the Lower Silurian formations. The Hannibal shales, from their loose texture and readily decomposable nature, wash down and form, almost invariably, a long and gentle slope or terrace, covering, for some distance, the underlying formations, thus making it extremely difficult to find the junction between these shales and the underlying beds. It is rarely, except in mine or well sections, and in a few other localities, that a systematic knowledge of the underlying beds can be obtained.

There has been much confusion in trying to determine the thin beds of exceedingly variable rock that underlie the Hannibal, and rest upon the First sandstone. Swallow,* in his report, has evidently frequently confused his Lithographic limestone (Louisiana) of the northern counties, which he notes as widely distributed through Polk and Greene counties, with the beds of the Devonian. He states, in the same report, that, towards the south, its lithological characters so change that it cannot be recognized except by its fossils and stratigraphical position. This statement from so careful an observer would

*Geol. Sur. Missouri, 1 and 2 Ann. Repts., p. 106, 1855.

indicate that he noted a difference between his typical Lithographic of the north, and this supposed Lithographic of Greene county. Not suspecting the formation of any other horizon between the First Magnesian of the Calciferous, and the Chouteau (Kinderhook) formation, and having no opportunity to study the fine exposures of the southwestern part of the area, it is natural that he should consider the Sac limestone of the Devonian as a local modification of his Lithographic.

The Louisiana limestone, it will be noted, is rarely present in Greene or Christian counties, and if present, occasionally merges insensibly into the Hannibal shales above, thus making it extremely difficult to separate the two. A similar difficulty is met in separating the First Magnesian from the beds underlying the Hannibal shales, or the Louisiana limestone, where the latter is present.

It will be noted, in the Chouteau, that a remarkable discoloration and impurity characterize its deposits. The waters, during the deposition of the Devonian, as well as the Chouteau, must have been impure and turbid, and generally unfavorable to animal life. Hall* calls attention to a similar condition in the Hamilton and so-called Chemung of Iowa, and this fact accounts for the general absence of fossils in the limestones of these formations. An irregular alternation of these beds of limestones, sandstones and shales will be noted, indicating a disturbed condition of the earth's crust at this time, in anticipation, as it were, of the unsettled condition of the strata which occurred during the deposition of the coal beds. This is very striking, after the long periods of quiet of the lower Silurian, during which such heavy beds of limestone were laid down. While the limestones of these Devonian beds are so generally destitute of animal remains, the shales, locally, are rich in fossils, as will be hereafter seen. This condition is also briefly noted by Hall†.

*Geology Iowa, vol. 1, p. 88, 1858.

†Ibid, p. 86.

The following horizons* have been fully synchronized in this area and adjoining counties. The following is a generalized section:

Phelps sandstone	0 to 4 feet
Sac limestone	1 to 18 feet
King limestone	1 to 15 feet
Eureka or Black shale	½ to 5 feet

Eureka Shale. The Black shale forms the base of the Devonian in this area, and ordinarily rests directly, with considerable unconformity, upon the First Magnesian limestone. In some places, particularly in the southern and southeastern portions of the district, and extra-limital, toward the south and southeast, there are strong reasons for suspecting that the gap between the Calciferous and the Devonian may contain some representations of the Upper Silurian or Lower Devonian, and that this hiatus may not be so great as heretofore supposed. A careful study of the outcrops along the lower James and its tributaries will, undoubtedly, throw light upon this subject.

The above name is given to this formation because of the highly carbonaceous condition of the rocks. The best exposures of these beds are found along the banks of the James river, particularly near the Frazer house (Tp. 27 N., R. XXII W., Sec. 29). From the ford, at the house, nearly to the shafts of the Delaware mining company, along the east bank of the river, the outcrops of this stratum show a thickness of from three to four feet. The middle portion of the shale is bluish-black, somewhat carbonaceous, soft, and fossiliferous, containing numerous well-preserved shells of Lingula (probably *L. subspatula*), and casts of Leiorhynchus, which the miners call "coon tracks," all of which are typical Chemung and Marcellus fossils†. The lower layers hold many fragmental plants, calamites being the most common. Iron pyrites is also abundant, and is believed by the prospectors to be rich in silver, an idea which, it is needless to say here, is wholly a delusion. The bottom of the shale merges, through a thin

*The names given to these beds are merely for convenience of description, and the horizons are somewhat fully dwelt upon here for the benefit of future students of this area.

†See article by H. S. Williams in Amer. Jour. Science, Feb., '95, in which is discussed the range of some Devonian fossils in rocks of the Carboniferous age.

seam of irregular bedded, rather fine-grained, bluish-gray sandstone, filled with minute particles of pyrites, and thirty-six inches of dark, highly silicious, carbonaceous limestone, into a shaly mottled, grayish-green limestone which immediately overlies the First Magnesian limestone. The shale weather into an ash-colored clay. The abundance of pyrites in the upper and lower layers calls attention to Saffords mention of a similar occurrance in the black shale of Tennessee*. The similarity of this shale to those just mentioned is very striking, and sufficient to indicate a strong probability of their equivalency. The same author notes (p. 331) the occurrence of similar fossils in that state, and also speaks of the fetid, fine-grained, bituminous sandstone, from a few inches to 15 feet in thickness lying just below the Black shale. Whitney† notes the characteristic presence of nodules of iron pyrites in the black shale of Illinois and the occurrence of the fossil Lingula, closely resembling the *L. subspatula*, which seems to confirm its identity with the Genessee of New York. Thus, from position, similarity of structure in the beds, and fossil remains, the conclusion is reached that the Eureka shale in this district is, undoubtedly, the equivalent of the Black shale of Tennessee. Simmons‡ places the Eureka shale, doubtfully in the Devonian. A study of the area between Greene county, Missouri, and Washington county, Arkansas, has indicated the undoubted equivalency between the Black shale of this district and the Eureka shale of that state. Branner states, in a footnote on p. 26 of the same report, the following: "The Eureka shale is the same as the Black shale of Safford in Tennessee." It is referred by him to the Devonian, but the fossils found, both in the Tennessee bed and in the Eureka shale of Arkansas, do not necessarily place this shale in the Devonian, but would as readily admit of its belonging to the lower Carboniferous.§

*Geology Tennessee, p. 329, 1869.

†Geol. Sur. Illinois, vol. 1, pp. 119-120, 1866.

‡Geol. Sur. Arkansas, Ann. Rept. 1888, vol. IV, p. 26, 1891.

§A careful study of the beds, both in Tennessee and Southwestern Missouri, since the above was written, has confirmed this view.

A careful tracing out of the formations from Missouri southward into Arkansas indicates the equivalency of the Boone chert and cherty limestone of Branner with the Augusta limestone of Missouri. In Tennessee, the Black shale directly underlies the lower, or Protean, member of the Silicious group of Safford,* which he considers the probable equivalent of the Keokuk or upper Burlington of Missouri. In a section in a quarry, near the Perry House at Eureka Springs, are found about 10 feet of crumpled carbonaceous shale (Eureka shale), underlying about 20 feet of what was determined to be Chouteau limestone. This last limestone was directly under the marble beds which have been traced, in their transitions, from the lower Burlington of Missouri. It was noticed that, in Washington county, the Eureka shale underlaid the Boone chert, or lower Burlington. At Eureka Springs, the Eureka shale underlies the Chouteau, and in Tennessee the Black shale underlies what is probably the equivalent of the upper Burlington limestone. In Missouri, the Eureka shale is separated from the Chouteau and lower Burlington limestone above by several well defined and widely distributed horizons, directly separated from the Chouteau by the Phelps sandstone, containing an abundance of coprolites and fish teeth, which have been noted at a large number of points and over a wide area, and which are characteristic fossils of the Hamilton, certainly of the Devonian system. There can be but little doubt, then, that these three shales are all Devonian.

There seems to be no regularity in the distribution of the Eureka shale. By far the best location for its study is near the southwestern corner of the area, on the James, at the Frazer place (Tp. 27 N., R. XXII W., Sec. 29, Se. qr.) It apparently disappears east of this point, and is either replaced by a highly silicious or cherty limestone which is somewhat shaly, as seen in the shafts of the numerous mining camps in Tp. 26 N., R. XIX W. (extra-limital), or else it is entirely unrepresented, and the deposits in this region belong to the King limestone. Sections in the Hornbeak mining camp, in

*Geology Tennessee, p. 338, 1869, par. 874, and p. 342, par. 886.

the southern part of Tp. 27 N., R. XIX W., which are somewhat similar to the sections of the township to the south, will be given and discussed when the mines of that locality are considered. To the southwest of the deposit at the Frazer place, throughout the whole of southwestern Missouri and northwestern Arkansas, as far as observation has gone, these shales are well exhibited wherever erosion has cut through to them, and they increase considerably in thickness to the south and west.

Penrose* states that overlying the Silurian formation in the Batesville region of Arkansas, there is a deposit of very irregular distribution and thickness, varying from nothing to 30 or 40 feet, "of a yellowish-brown or gray, earthy sandstone, often containing green or black layers." These deposits, particularly the shale, are developed on a much larger scale to the west, and are described under the name of "Sylamore" sandstone. Williams supposes them to be the equivalent of the Black shale of Tennessee.

In the northeastern part of the area, in a well sunk on the Mitchell farm (Tp. 30 N., R. XIX W., Sec. 9, Sw. ¼ of Ne. qr.), six feet of bluish shale were passed through, overlying 10 feet of First sandstone. The well was sunk 95 feet further in Second Magnesian limestone. To the north and northwest, no outcrops are found until the section at Presley hill is reached, near the southeast corner of Tp. 31 N., R. XXII W., Sec. 19. Here, in a gully to the east of the road and about 200 feet south of the ford, overlying the First Magnesian limestone, which forms the bed of the Sac, are found five inches of a black to yellowish shale, weathering to a very tenacious clay, which, upon drying, tends to break into more or less prismatic blocks. As these clayey shales directly underlie the King limestone they are, undoubtedly, the equivalent of the shales now under discussion, though no fossils were found. It is quite probable that these shales have a much wider distribution to the northwest, north and east, but, owing to their destructible nature and the fact that they nowhere have a thickness of more than

*Geol. Sur. Arkansas, Ann. Rept. 1890, vol I, p. 114, 1891.

two to six feet, they at present are, undoubtedly, covered by the slope. Whenever more drill-wells are put down, more data can be obtained. On the Cash farm (Tp. 31 N., R. XXI W., Sec. 32, Sw. qr.) in a shaft sunk in the bluff close to Sims branch, a very peculiar variation of what was determined as these shales was found. About six to eight inches of a bluish-green shale outcrops over the First Magnesian limestone. This shale containes a large number of oval and rounded, water-worn pebbles, half an inch in diameter, and composed of very hard agatized chert. Five hundred feet to the northwest, on the slope of a rounded knob, a shaft was sunk to the depth of 35 feet, and then abandoned. This shaft first passed through a few feet of the lower layers of Hannibal shale. The dump was covered with fragments of Sac limestone, and the material last taken out was identified, without much doubt, as Black shale.

King Limestone. The name given to this formation is not indicative of any local peculiarities at this particular point. In this area it is very thin, and, like the Phelps sandstone, usually covered by soil. It is rarely over a foot or two in thickness, except outside and south of the area. No fossils of any kind have been found, and it has only been determined by position and lithological characters, the latter being sufficiently distinctive to make it easily recognizable in mine sections, or wherever exposed. Tumbled, decomposed blocks are not uncommon in ravines and creek beds, though it is often difficult to trace them to their original positions. This limestone, the "cotton rock" of the miners, is soft, very fine-grained, compact, of a light ashy gray color, and in all cases thus far observed, made up of thin, frequently very thin, alternating layers of hard and soft material, the dolomitic and more calcareous limerock forming, on its weathered surfaces, narrow ridges and grooves representing successive laminæ. This frequent alternation in composition greatly facilitates rapid decomposition of the strata. In such cases, it is likely to be confused with very similar beds of the First and Second Magnesian limestones, and can then only be determined by position. In other cases, this

rock, where weathered, presents extremely delicate lines and streaks which, under the microscope, and occasionally to the naked eye, exhibit the minute dendritic markings of manganese dioxide. This rock, as one would expect, as the dolomitic limestones of the Calciferous are approached, contains a larger amount of magnesia. White* has called attention to the abundance of magnesia in the Silurian, and the gradually diminishing amount in the Devonian age, the limestones of the latter being composed "in part of magnesian strata and in part of common limestone." Thus the King limestone seems to form a bed of passage from the purer, deep sea limestones of the Calciferous to the impure deposits of the upper Devonian and Chouteau above, which were formed in more or less turbid waters. Occasionally, as in the outcrop in the gully at the foot of Presley hill (Tp. 31 N., R. XXII W., Sec. 16, Ne. qr.), this rock merges into a light, whitish, impure clay. Of all the formations represented in the Southwest, there is none that decomposes and breaks down so rapidly as this limestone. Disintegrating and washing out from beneath the overlying Sac limestone, it leaves that horizon overhanging and forming a low escarpment along the gullies and streams that cut through it. Lithologically, this rock seems to agree somewhat with Shumard's† description of the Onondaga limestone, with the exception of position and the intercalations of chert and cherty concretions found in the latter. Swallow‡ also notes the bluish-green colorations sometimes found in the Onondaga limestone. It is far more probable, however, that this formation is a member of the Hamilton.

This formation, in the northern and eastern portions of the area, almost invariably underlies the Sac limestone, as far as observed. To the south, where it usually outcrops along the James and the tributaries that cut through this limestone, it underlies, directly, the Phelps sandstone, the Sac limestone being absent. Here it rapidly thickens, increasing outside the

*Geology Iowa, vol. I, p. 185, 1870.

†Geol. Survey Missouri, I and II Ann. Repts, p. 107, 1855.

‡Ibid, p. 108.

area toward the south. It is absent, however, at the shafts of the Delaware mining company, near Frazer's.

At the Newton mound, there is an outcropping of about 8 to 10 feet of this limestone, typical in structure and general lithological characteristics. Tumbled blocks are seen all along the slope, and occasionally, in the more abrupt portions of the slope, the bedded limestone may be seen. Between the Sac limestone and this formation there are about 5 feet of hard, fine-grained sandstone, in two beds. In places this sandstone shows stratification marks, or thin bedding planes, and merges, insensibly, below, into the King limestone, forming a bed of passage between this and the silicious Sac limestone above. Its presence is also inferred from a few broken blocks on the slope of Goodnight mound (Tp. 31 N., R. XXI W., Sec. 2, Nw. qr.) It probably underlies the Sac limestone in the Cowden mound (Tp. 31 N., R. XXI W., Sec. 9, Se. qr. of Sw. qr.), as it is so uniformly found in this area. It may also be seen in Tp. 32 N., R. XXIII W., Sec. 36, in a dry branch extending north from the ford at the Sac. It thins out rapidly in this direction, and in a section obtained (in Tp. 31 N., R. XXIII W., Sec. 1, Se. qr. of Ne. qr.) it seems to be almost wholly replaced by 3 feet of soft sandstone, separated from the Sac limestone above by a one-foot bed of a soft, silicious limestone. The block faults near the foot of the Bird Eye hollow expose, at various points on the stream, the wreckage of this horizon. The same condition appears in the Presley hill faults. This formation may also be studied at the following points: At the Johnson mines, Tp. 30 N., R. XX W., middle of Sec. 29; at various points along the head of Sims branch, in the southeastern part of Tp. 31 N., R. XXII W., Sec. 32; on King branch, in the southern part of Tp. 31 N., R. XXII W.; especially at King mound, in the northeast of Tp. 31 N., R. XXII W., Sec. 27, in the gullies that have been washed out around the base of the mound; along the bluff on the west side of the Sac, south of the Johnson mines (Tp. 32 N., R. XXIII W., Sec. 29); and in the Hornbeak mines (Tp. 27 N., R. XIX W., Sec. 36), where numerous shafts have passed through it and the dumps are

found covered with broken blocks having the characteristic structure.

The readily decomposable nature of this rock is well illustrated in the bluff along the Sac south of the Johnson ford (Tp. 32 N., R. XXIII W., Sec. 29). Here the Sac limestone from its durable nature, forms, in places, a bench or protruding shelf along the river. Locally, at several points, seepage springs from above have washed down and replaced the eroded King limestone by a secondary deposit of calcareous tufa, containing numerous land shells of the genera Helix and Pupa. This rock would probably form an excellent hydraulic lime, similiar to that made from the beds of the Devonian occuring in so many places.

Sac Limestone. But little unconformity exists between this layer and the Phelps sandstone above. Occasionally a thin layer of clay, which has been noted only in one or two mine sections, marks the separation which is usually indicated only by a slight irregularity of surface. The typical rock outcrops at various points along the Sac river and its branches—hence the name. It is also well exposed along the bluffs of Panther creek, in Webster county. It is a very handsome rock, and where the layers are thick enough and free from pyrites, would form a very durable building stone, as it withstands weathering well. It is a massive, purplish-gray or drab magnesian limestone, mottled with irregular patches of a faint greenish tinge. In texture it is very compact and crystalline, the blow of the hammer leaving a bruised mark on the broken fragment similar to that left on the lower Burlington limestone. Frequently there are minute, irregular cavites, and locally a stylolitic layer occurs. Where this is present, fossils should be carefully looked for. This member is rarely more than ten feet thick, and averages from four to eight feet. In some localities it is extremely hard and more crystalline, in which cases the small cavites already referred to are considerably larger than ordinary. In places, particularly in the northeastern quarter of the area, the layers contain much iron pyrites, frequently in large cubical crystals or in irregular

crystalline masses. In such cases, where weathered, the rock is filled with "pot-holes," and is covered with large dark blotches from the decomposition of the pyrites. This is especially noticeable in Tp. 32 N., R. XX W., Sec. 24, in the "draws" that enter the headwaters of the Pomme de Terre. Locally, the limestone becomes cherty, containing layers or masses of a very hard, bluish, chalcedonized and agatized chert, and also merges rapidly into a softer, ferruginous and porous variety.

This formation seems to be generally absent in the south half of the area, except along Panther creek, and, doubtfully, in the drill-well section at Springfield. In the north half of the area it is the most striking and characteristic horizon of the Devonian beds. The rock is very durable, and forms a foundation for the Hannibal slope, thus making a broad terrace. Where erosion has cut through from the lower Burlington above, and to the Calciferous below, in bluffs, and particularly in mounds, there exists a system of double terraces which form very striking features in the scenery. In such cases are seen the more or less abrupt lower Burlington slope, a narrow Chouteau terrace, a long and gentle Hannibal slope, and the broad Sac limestone terrace. The best example of the single terrace is found at King mound (Tp. 31 N., R. XXII W., Sec. 27, Ne. ¼ of Ne. qr.,) where there is a fine mound of circumdenudation—a flat top of Hannibal sandstone protecting the shales beneath, giving an abrupt slope to the encircling terrace, which is 100 to 150 feet broad. An outer circle of First Magnesian limestone forms a second incomplete terrace. Other fine examples may be found along Sims branch (Tp. 31 N., R. XIX W.), and the water of the Sac in the same township and range. An example of the double terrace may be found in the bluff on the west side of Sac river, in Tp. 32 N., R. XXIII W. Here is a good exhibition of erosion from the upper Burlington through to the Second Magnesian formation.

Other interesting points for the study of this formation are at Newton mound (Tp. 31 N., R. XXI W., Sec. 1, N. ½ of Ne. qr.) where the 10 feet or more of rock presents a very beautiful sparkling appearance, of bluish-gray color, with a

purplish tinge, very fine-grained, hard and compact; along Presley hill, on the Bolivar road (Tp. 31 N., R. XXI W., Sec. 16, Ne. qr.), near the ford, on both sides of the Sac, especially near the school house; at several places where the Graydon-Northview articline is broken into block faults; also on the southern slope of the Morrisville-Brighton fold on the Bolivar road (Tp. 31 N., R. XXII W., Sec. 36), where the following section shows great variation in this Devonian. Under 10 feet of Louisiana limestone are found 2 feet of slope, either representing unconformity or Phelps sandstone. No blocks of the sandstone were found, although careful search was made for them. First came 4 feet of more or less stratified, weathered, very compact, fine-grained, hard, silicious limestone, bluish-drab in color with a faint purplish tinge, the surface of which was deeply grooved by erosion to a depth of 6 to 8 inches in irregular lines, presenting a very remarkable appearance. Next came 1 foot of softer material, exposed only in the ditch, and elsewhere covered by a long slope, probably representing the King limestone. Then 3 feet of white, soft, arenaceous sandstone, covered by a thin layer of silicious limestone. The 6 feet from here to the Sac river represented the First Magnesian, a highly silicious limestone, with the characteristic irregular, yellowish cavities filled with a less indurated matter.

Southwest of the center of Tp. 31 N., R. XXI W., Sec. 33, in a little draw that heads on the McCurdy place, on the north side of Sims branch, just south of the neighborhood road, the wet weather drainage has exposed a considerable surface of this horizon. Here a few brachiopod remains were found, so poorly preserved that it is impossible to name them. One, however, closely resembles *Spirifer marionensis*. This would be the best point found in the area for a careful search for the fossils of this formation. The rock here is coarse, crystalline, and weathers in such a manner as to leave obscure casts of crinoid stems in relief on the surface, giving it a rough appearance. It is barely possible that this particular rock may be Louisiana, and not Sac limestone. The upper layers are thin

and shaly, and contain crystals of iron pyrites. The middle and lower layers are thicker-bedded.

On the Cochran farm (Tp. 31 N., R. XXI W., Sec. 6), just south of Pleasant Hope, this rock is much finer-grained, and the upper layers are filled with numerous cubical or octahedral crystals of iron pyrites from one-eighth to one-fourth of an inch in diameter. Here the lower layers have a rich coloring, the gray being mixed with a light chocolate or fawn color, dotted with the characteristic greenish splashes.

In Tp. 29 N., R. XIX W., Sec. 28, along Panther creek, the rock is very much lighter colored, more compact, finer-grained and harder, though occasionally speckled with minute calcite crystals. South of this, it becomes more attenuated, and loses its purplish drab color, leaving its lithological characters quite indefinite.

A fine bluff of Sac limestone outcrops along the Sac on the line between sections 21 and 22, Tp. 30 N., R. XX W. It stands out as a bold shelf midway up the bluff. The scarceness of fossils in this formation has been noted; and there is frequent difficulty, on account of lithological characters, in separating it from the Louisiana when the Phelps sandstone is absent. So far, no chert has ever been found in the Louisiana, and as it is of frequent occurrence in the Sac limestone, it is a valuable lithological mark of separation between the two.

Phelps Sandstone. The Phelps sandstone is usually separated from the formation above it by a few inches of clay, or by a soft, impure, sandy clay, representing the unconformity between the Devonian and the Lower Carboniferous. It is a noticeable fact that, when the Devonian is present, the Louisiana limestone is usually, though not always, absent, and hence the Phelps sandstone generally underlies the Hannibal shale. The 2 or 3 inches of clay above referred to varies exceedingly. Attention should be called here to the slight unconformity which this clay represents between two such widely separated ages, and it brings to notice once more the oft-discussed problem of the true position of the Hannibal beds, *i. e.*, whether Devonian or Lower Carboniferous. So eminent an authority

as Hall has stated that he saw no reason to change his frequently-expressed opinion of the strong Devonian cast of the Kinderhook beds.

The sandstone above the limestone layers, and best shown, perhaps, at the Phelps mines, is a very peculiar rock. Though nowhere exceeding four feet in thickness, it is never mistaken for any of the other sandstones. It varies from a soft, irregularly bedded, rather coarse-grained sand-rock of a watery-green color, to an almost limpid quartzite-like stratum. Frequently, masses of limpid quartz are surrounded by an impure chert, which passes gradually into the soft, friable sandstone* a few feet away. The grains in the coarser varieties are more or less rounded, pellucid quartz, and cemented by a magnesian lime. Almost invariably the sandstone forms a matrix for more or less angular, water-worn, flint pebbles, which vary from the size of a mustard seed up to two inches in diameter. These pebbles are of chert, frequently agatized, and range in color from milky white through shades of pink and blue to bluish-black, though when broken they almost always present an opaque, milky-white interior. They closely resemble the cherts of the First and Second Magnesian limestones, and the sandstone undoubtedly represents an off-shore or old beach deposit. Occasionally, as near the head of Asher creek (Tp. 30 N., R. XXIII W., Sec. 9), the sandstone presents a very brilliant, glistening surface, and were it not for the pebbles before described, might easily be taken for the First sandstone.

*It should, perhaps, be noted here that there is a prevalent greenish cast in all the beds of the Devonian formation in Southwest Missouri. Penrose (Geol. Sur. Arkansas, Ann. Rept. 1890, vol. I, p. 119) calls attention to this coloration in the rocks below the Izard limestone in Arkansas. He suggests that this watery-green color is probably due to the presence of the proto salts of iron, since, on an exposed surface, the green color changes to a yellow or brown color which permeates the surface to the depth of an inch or more. When the green coloration is striking in a freshly-exposed surface of the Phelps sandstone, the weathered surface always presents a dark yellowish-brown crust. This same coloration is frequently observed upon the weather-exposed surface of the Sac limestone, particularly when the rock possesses the greenish mottling which is so common a characteristic in the northern portion of the area. Hall and Whitney (Geology Iowa, vol I, pp. 86 and 87, 1858) note this greenish coloration as a characteristic of the Hamilton of Iowa.

An important feature of this formation is the presence of fish teeth, which occur abundantly, and which are widely distributed, all being water-worn, showing evidence of having been tumbled by the waves over this ancient beach. They vary from the size of a grain of wheat up to half an inch in diameter. They are dark bluish-black in color, polished by wave action, and distinctly exhibit all the microscopic characters. Some of these have been identified as *Ptyctodus calceolus*. Dr. Newberry, of Columbia college, New York, the highest authority on paleozoic fishes, states, in a private communication, that those sent him very closely resemble the above genus, which belongs to the Elasmobranchs, and probably to the Chimeroid group. Dr. Newberry further states that he has found these teeth abundant in the Hamilton of the Devonian in Iowa and Illinois.* Numerous coprolites are also found. Undoubtedly other species, from material collected in this area, will be identified by further research.

The weathering of the Phelps sandstone is, locally, extremely peculiar, and differs from that of any of the other sandstones. Frequently rounded, branched elevations, like large seaweeds, are left exposed on the surface, and these are sometimes undermined, leaving bridges and arches standing out like loosely tangled masses of cord; or a surface is covered by ridges like those made by the pouring of some extremely viscid substance.

The best locations for the study of this sandstone are as follows: In Tp. 28 N., R. XXI W., Sec. 1, Nw. ¼ of Nw. qr., at the Phelps mines, numerous shafts cut through the Chouteau into this sandstone, and the old dumps around the shafts form a good collecting ground for the fish teeth and the variations of the sandstone, from the quartzite, before described, to the strangely weathered forms just referred to. The formation here averages about two feet in thickness. As these mines were the point of the first discovery of the fish teeth, as well as the place where the peculiar weathering and other char-

*Geol. Sur. Illinois, vol. II, p. 106, pl. 10, fig. 10, 1866; also 35th Ann. Rept. N. Y. State Mus., p. 206, pl. 16, figs. 12-14, 1881.

acteristics are best exhibited, the provisional name of Phelps sandstone has been given to this horizon. The richest deposits of fish teeth have been found near the center of the camp, along the main crevice.

At the Pierson creek mines (Tp. 29 N., R. XXI W., Sec. 35) the floors of the drifts rest upon the top of this sandstone.

In Tp. 27 N., R. XXII W. Sec. 29, Sw. ¼ of Se. qr., are the shafts sunk by the Delaware mining company. From 4 to 6 inches of sandstone quite similar to the deposit found at the Phelps mines are seen here, but the chert pebbles are more abundant and striking. These mines are situated in a narrow gorge that heads a few hundred feet east of the James river, and were worked with the expectation of finding silver in the pyrites that abounds in the Eureka shales of the southwest Missouri Devonian. The bluffs on each side of this gorge are capped with Burlington chert, and a good section was obtained here of the Chouteau, Hannibal shales, Devonian beds, and the Frst Magnesian limestone which lies in the bed of the James.

Of the drill-well sections in the city of Springfield, that at the "Frisco" car shops indicates 4 feet of Phelps sandstone; one of the Frick ice company wells indicates its presence; while that at the Metropolitan railway power house does not indicate its presence. No other authentic outcrops are found south of Springfield. In the North half of the area, however, the Phelps sandstone is fully exposed, and a number of good sections have been observed. Only a few typical examples will be mentioned.

At the Johnson mines (Tp. 30 N., R. XX W., Sec. 29, Se. qr.) which were sunk in prospecting for silver, 4 feet of Phelps sandstone very closely resembling that found at the Phelps mines in structure and general characters, and abounding in fish teeth, were passed through in shaft No. 2. The record in shaft No. 3, about 500 feet west of No. 2, was not so perfect, but indicated about 7 feet, and a considerable amount of the rock was found in the dump.

At the Newton mound, in the southeast corner of Polk county (Tp. 31 N., R. XXI W., Sec. 1, N. ½ of Ne. qr.) a number of fragments of the typical sandstone with fish teeth were found on the slope. A hurried search did not discover this sandstone uncovered. It is undoubtedly covered by the Hannibal shale, and is, probably, not much more than one foot in thickness. A prospect shaft sunk on the Kræmer farm (Tp. 27 N., R. XX W., Sec. 11, Se. qr.) passed through this sandstone, filled with the characteristic fish teeth.

Loose fragments were picked up on the Cochran farm (Tp. 31 N., R. XXI W., Sec. 6, Ne. qr.). No fish teeth were found. This formation is also found on the Cash farm (Tp. 31 N., R. XXI W., Sec. 32). The drill-well passed through 2 feet of this sandstone at a depth of 141 feet (Tp. 32 N., R. XXII W., Sec. 36). On the Craig farm, 2 miles north of Hickory Barrens (Tp. 31 N., R. XXI W.) 2 feet of this sandstone were noted at a depth of 100 feet.

On the north line of the E. ½ of lot 4 (Tp. 29 N., R. XXI W., Sec. 25, Ne. qr.), at the fault, a shaft was sunk 18 feet, which penetrated the Phelps sandstone, at which point the latter rests against the beds of the upper Burlington limestone. The sandstone is about three feet thick here, a very compact, fine-grained rock, merging into a quartzite, magnesian lime being the cementing material, which, in the weathering of coarser-grained specimens, forms whitish clay-like efflorescence on the surface. Some weathered blocks on the dump at this shaft show, very plainly, fucoid-like markings.

Beds of this sandstone have been found as far south as Boone county, Arkansas. In Tp. 21 N., R. XX W., Sec. 18, of that state, a section of 3 feet of this sandstone is found on a bluff on the McMerrie tract.

Where erosion has not cut through the First Magnesian limestone, the soil left by the wreckage of the Devonian is wonderfully rich, the mixture of the Phelps sandstone, the Sac limestone and the King limestone, varying as they do in their composition, furnishing eminently favorable conditions

for abundant crops. The splendid farms in the northeast part of Tp. 30 N., R. XX W, near the head of Sims branch and Dry Sac creek, in the southern half of Tp. 31 N., R. XXI W., are good examples of the fertility of the soils derived from these members of the Devonian beds.

CARBONIFEROUS.

The great subdivisions of the Carboniferous are recognizable in southwest Missouri as a lower part, or Mississippian Series, and an upper part, or Des Moines series (coal measures). The former occupies the larger part of the district included in this report, and is represented by several well-marked members. The latter is represented only by isolated outliers of the coal fields situated farther to the west.

MISSISSIPPIAN SERIES.

The Mississippian series, or Lower Carboniferous is composed almost wholly of heavily bedded limestones which are, in great part, crinoidal, though occasionally magnesian beds occur. In Greene county the series is represented by two of the four sub-divisions recognized in the Mississippi basin. These are the Kinderhook and the Augusta.

Kinderhook. The probable equivalents are the Chouteau group, of Missouri; the Kinderhook, of Illinois; the Goniatite limestone, of Indiana; the Marshall, of Michigan; the Yellow sandstone, of Iowa; the Silicious group, lowest beds, of Tennesee; and perhaps also the Catskill.

Heretofore, the name "Chouteau group" has been applied to the beds in this group by some geologists, but Miller* gives priority to the name "Waverly," as adopted by Briggs, in 1838, in the report of the Geological Survey of Ohio, from the beds exposed at Waverly, in that state. Swallow, in his report of 1855, calls this the Chemung group, believing that they were Devonian beds. Hall, of New York, still adheres to this belief. Meek and Worthen†, in 1861, after a careful study of the Illinois, Missouri and Indiana beds, proposed the name Kinderhook.

*North American Geology and Palentology, p. 68, 1890.
†Geol. Sur. Illinois, vol. I, p. 108, 1866.

The position of this formation has been pretty definitely settled as being in the lower part of the Lower Carboniferous system, and it is rather late in the day to raise any doubts in regard to this decision. But a study of these beds in southwestern Missouri and northwestern Arkansas will force this doubt upon the careful investigator. The unconformity between this formation and the Burlington above, and the lack of unconformity and similarity of the deposits between this and the Devonian below, together with the abundance of the *Fucoides caudagalli* and also the strong Devonian cast of other fossils of this area, which was noticed by Dr. Hall, in his examination of the Drury College collection, will perhaps, account for this reference to a question that has seemed for some time, a settled one.

The formation, though ordinarily not very thick, is perhaps the most easily recognized, lithologically, of any formation in the southwest. And this is fortunate, for except in a few localities, fossils are extremely rare in this district. There is a natural division of the rocks into three distinct beds:

Chouteau limestone	8 to 30 feet.
Hannibal sandstones and shales	10 to 90 "
Louisiana limestone	0 to 8 "

The figures give the minimum and maximum thickness in the area. As has just been stated, the separation between these beds and the lower Burlington above is represented by more or less unconformity. The strata of this group graduate, in many cases, so insensibly into each other that one is frequently led to doubt the propriety of separating them, and it is difficult to say where the lithological or palæontological characters begin or end. This is particularly true of the Chouteau and Hannibal. In many cases, where the sandstone is wanting, the Chouteau merges insensibly into the Hannibal shales, so it is impossible to say where one begins and the other ends. No unconformity has been noticed between these beds.

In Iowa,* the Kinderhook beds (Chouteau) are made up largely of sandstones and limestones, with several character-

*Geology Iowa, vol. I., p. 194, 1870.

istic oolitic layers. These form characteristic beds in Illinois,* and it is worthy of notice that they are wholly absent in Missouri. In this state, and particularly in the area under discussion, the limestones and shales predominate, and in a large part of the district the sandstones are entirely absent. Along the slopes of the Springfield fold, and particularly the southern slopes, the Hannibal is made up largely of sandstone and the Chouteau is more arenaceous. Going southward, the sandstone rapidly thins out and is replaced by shales. About 12 miles from the axis of the Springfield fold, a line drawn east and west and parallel to the axis will mark, essentially, the line of demarcation where the Hannibal sandstone passes out and the shale predominates. The sandstone is rarely seen farther south except near the crests of elevated folds. The reason is obvious, since the sandstones accumulate as an off shore deposit, and the shales are formed in deeper and quieter waters.

Louisiana Limestone. The lowest member of the Carboniferous is not so variable in composition and texture as the other two. It frequently, however, possesses such lithological characters as to make it difficult to distinguish it from the associated Devonian rocks. As only a few obscure fragments of fossils have been found in this region, its identification is dependent entirely upon position and lithological characters.

The best exposures of this formation thus far noted in this area, are at the Newton mound in the extreme southeastern corner of Polk county (Tp. 31 N., R. XXI W., Sec. 1, Ne. qr.). Immediately underlying the Hannibal shales, and overlying the Phelps sandstone, are ten feet of this limestone. The upper layers are hard, fissile, and buff in color. Where this layer weathers, in broken blocks and on exposed surfaces, the coloring matter is leached out, leaving the rocks much lighter. A few inches underneath the shaly layers is a stratum much heavier, lighter colored, and with a faint reddish to yellowish tinge when freshly broken. The weathered surface of the middle beds, as well as the lower, present a rough, minutely nodular surface from the exposure of very small fragments of

*Geology Illinois, vol. 1., p. 108, 1866.

crinoid stems. The beds are very compact, hard and fine-grained. Weathered fragments, when held suspended in the hand and struck with a hammer, ring like phonolite. This characteristic is more striking in the lower beds, though usually possessed by the middle layers. Occasionally small fragments of calcite are scattered through the rock, also small crystals of pyrites. At Newton mound, thin, very regular streaks of calcite, merging into larger patches are sometimes present. It will be seen, then, that there is an easy transition from the very soft upper Hannibal shales, through the harder lower beds of the same formation, as found in the Holman and Gilmore quarries, to the thin, shaly, transition beds of the upper Louisiana, and the strongly indurated, compact, and heavy beds of the lower Louisiana.

The best points for the study of this formation are the following locations: On the Cowden and Albright farms (Tp. 31 N., R. XXI W., Sec. 9, S. ½); on the Cochran farm, Ne. corner of Sec. 6, same range and township, where it is associated with the Devonian; in Tp. 32 N., R. XXI. W., Sec. 30, Sw. ¼ of Sw. qr; and in Tp. 32 N., R. XXII W., Sec. 23, both in the Ne. and Se. qrs. Along the Sac river, particularly just east of the ford on the Springfield-Morrisville road (Tp. 32 N, R. XXIII W., Sec. 36), is a good outcropping of the Louisiana. It is 10 feet thick, and presents characteristics similar to those exhibited at the Newton mound. At the McCracken place (Tp. 29 N., R. XXI W., Sec. 5), is seen an outcropping of what seems to be some eight or ten feet of Louisiana, though it may prove to be a somewhat modified form of Sac limestone. At this point it underlies the Hannibal shales, and the two are elevated, by the faulting, to the same plane as the upper Burlington. Here it is reddish in color, and, though more coarsely crystalline than usual, is compact, hard, and carries some pyrites. Nearly due west, about a quarter of a mile, along the line of fault, and in a small quarry on the west bank of the stream flowing from Sander spring, is found a most interesting modification of this same rock. The Upper Burlington to the south of the fault is much tumbled and broken, and the supposed

Louisiana, or possibly the Sac limestone, being a much stronger rock, has undergone a slight metamorphism and has developed cleavage planes which exhibit by reflected light, a glistening surface strikingly resembling felspar. It is well exposed in the long slope of the Birdeye hollow road (Tp. 31 N., R. XXII W., Sec. 29), and also near the top of Presley hill (Tp. 31 N., R. XXII W., Sec. 22, Sw. qrs.).

As this rock is nowhere very thick and has so limited a distribution in the district, its uses are very few. Some local beds might, possibly, make a handsome, and certainly a durable building stone. No fossils have been found except on weathered surfaces, where a few imperfect crinoid stems are often exposed.

Hannibal Shales. The very inappropriate name of vermicular for this division of the Kinderhook was given by the early workers in the state upon the supposition that the tortuous tube-like cavities that penetrate the sandstone of these beds were worm borings. These tube-like impressions are doubtless the remains of fucoids, or sea weeds. Owen, long ago, in 1858, suggested this fact. Hall, after a careful study of specimens collected from this area, pronounced them of vegetable origin.

The formation is made up of, usually, two members, an upper, which is commonly a yellowish sandstone penetrated everywhere by worm-like borings that are filled with less indurated matter, and a lower or bluish, compact shale. The formation is not sharply separated from the Chouteau above, and where the sandstone is wanting, as is frequently the case, the Chouteau merges so insensibly into the shales beneath that it is next to impossible to establish any line of demarcation between them. The formation has a thickness of from 10 to 100 feet, the sandstone ranging from a few to, perhaps, 25 feet, and the shales from 25 to 75 or 80 feet. The latter seem to be always present, and usually increase in thickness wherever the sandstone decreases, or is absent. Like the Chouteau, this formation is exposed first where the streams cut through the overlying strata into it, and second, where a fold or fault

brings it up to the surface. The sandstone is quite durable, and in weathering usually forms benches or terraces protecting the softer and more easily decomposed shales beneath, in some cases forming flat-topped mounds or buttes. The sandstone varies in color from a light to dark yellow or reddish, the latter color being usually found in eroded surface blocks that have been burned by prairie or forest fires. In the degree of induration there is also much variation, the upper part being usually more or less friable, penetrated in every direction by the "borings" before referred to.

The sandy portion graduates through beds which become less and less arenaceous, into blue silico-magnesian shales which are from 5 to 70 feet thick. These are compact, usually grayish to blue, but in some places somewhat greenish in color. Frequently they show upon exposed masses a pure white, soft coating of magnesian material, about one-sixteenth of an inch thick. This white coating is sometimes mistaken for kaolin, which it resembles in physical characters only. The shales vary decidedly in hardness, in some places being very soft. When exposed to the air they decompose rapidly into a bluish-green clayey mud, which makes exceedingly bad roads in wet weather, and which, when mixed with decomposed Chouteau, makes a wonderfully rich soil. Swallow* states that the clays, when mixed with too much of the sandstone above, have an injurious effect upon the soil. This is rarely the case in this district. In other localities these beds are much harder, and while still possessing their shaly character, and breaking with a conchoidal fracture, they are so compact as to be easily separated into rough slabs, excellent for curbing and flagging. The latter condition is found mainly in the southern part of the area. Usually the shales are much softer when associated with the sandstone. Frequently this layer contains nodular, elliptical masses of impure iron pyrites. Almost everywhere it is covered with cauda-galli markings, which are brought out more fully in the blocks that are weathered.

*Geo. Rep. Southwestern Branch Pacific Railway, 1859, p. 6.

Along the southern slope of the Springfield fold, the sandstone is quite thick, though the well-sections in Springfield indicate only the presence of the shales. Going still farther southward, it rapidly thins out, and soon disappears south of the line drawn from the James river mines (Tp. 28 N., R. XXI W., Sec. 1) to a point near the "Devil's Den," (Tp. 28 N., R. XIX W., Sec. 3). Only the shales are found in the area south of this line, except along the upper slopes of some of the folds outside of the district. The well-sections at Springfield give a little over 40 feet of these shales. Going east, outcroppings 30 to 40 feet thick occasionally occur along Pierson Creek. At the Pierson Creek mines (Tp. 29 N., R. XXI W., Sec. 35) it forms the ore horizon. At the iron bridge across the James, a short distance to the east, the top of the shales forms the bed of the river. From this point eastward along the river and its branches throughout the greater part of the district, these beds form a characteristic feature of the landscape, and in many cases aid in forming the rich and productive bottom lands. One of the most picturesque points, and a typical example of the beds in this part of the district, is at Little Yosemite spring (Tp. 29 N., R. XX W., Sec. 28, Ne. qr.). About a quarter of a mile south of the main road the gentle slope formed by the shales on the east side of the James is abruptly terminated by a small branch that has its source in several springs that issue from the face of a bluff at the head of a narrow gorge. The main spring, a Burlington-Chouteau contact spring, has cut out this gorge, and falls in diminutive cascades over the alternating beds below. The striking contrast in the color of the rocks, from the dark bluish gray of the lower Burlington to the dark yellow of the Chouteau and the bluish-green shales beneath, together with the luxuriant growth of beautiful mosses and ferns, forms one of the most picturesque and attractive spots in the whole region.

Along the Finley and its branches, from near Linden (Tp. 27 N., R. XX W.), eastward, throughout the area, rather thin beds of Chouteau and Hannibal outcrop at various points, when not covered with Burlington slope. The Chouteau

rarely exceeds ten feet in thickness, and the Hannibal shale is from five to fifteen feet thick. Just below Gilmore's mill on the Finley (Tp. 27 N., R. XXII W., Sec. 36) are several quarries in the harder lower beds of the Hannibal shales. The following section was obtained just over the line of this area :

Chouteau limestone	5 ft.
Hannibal shales as follows:	8 ft.
Thin soft, light colored shale. (transition layer)	2 in.
Faint blue, harder shales	1 ft.
Very soft blue shales	6 in.
Harder Hannibal limestone	2 ft.
Softer rotten shales	6 in.
Thin-bedded, harder, light-blue limestone	4 ft.

Near T. J. Frazer's (Tp. 27 N., R. XXII W., Sec. 29), on the James river, under 10 feet of Chouteau, are found about 20 feet of somewhat varigated blue and gray limestone, rather hard and compact, and breaking with conchoidal fracture. To the north, the Hannibal, like the Chouteau, is mainly confined to a belt of country north of the Graydon-Northview anticline, and the southern slopes of the Morrisville fold.

Near the headwater of the Pomme de Terre (Tp. 30 N., R. XX W.), about 15 feet of the Hannibal shales underlie a few feet of sandstone. From here northwestward are various outcroppings, but it is not always easy to accurately determine the thickness of the formation on account of the tilting and crumpling caused by faulting and the effects of subsequent erosion. A few instances will be mentioned to illustrate the variation in thickness. At the Johnson mines (Tp. 30 N., R. XX W., Sec. 29), in shaft No. 2, 18 feet of the sandstone and 37 feet of the shales were passed through. Two miles north of Hickory barrens, on the Craig farm (Tp. 31 N., R. XXI W.), a well was sunk through 15 feet of Hannibal sandstone, and 35 feet of the shales. At the Fair Grove mound, under 80 feet of the conglomerate, 35 feet of bedded Hannibal sandstone lie exposed. A slope of debris extending to the base of the mound, makes it impossible to determine how much of the shales is present. At the Headlee spring (Tp. 31 N., R. XXI W., Sec. 34), under 35 feet of Chouteau, 20 feet of Hannibal sandstones and shales are found. A few miles to the northwest (Tp. 31 N., R. XXI

W., Sec. 20, Nw. ¼, of Sw. qr.), 45 feet of the sandstones and shales are exposed. At King butte (Tp. 31 N., R. XXII W., Sec. 27), is found one of the finest examples in the Southwest of a mound of circumdenudation, showing the protective influence of the hard sandstone over the soft and more easily decomposed shales, as well as the manner in which the shales run off over the hard Devonian beneath, and form the broad terraces. This mound is about 80 by 40 feet on top and about 40 feet high above the terrace which surrounds the mound. with a width of from 80 to 100 feet. The capping Hannibal sandstone is not more than from 5 to 8 feet thick, overhanging, in places, the decomposing shales beneath, which have a thickness of about 60 feet at this point. The mound and the terrace present, to the observer, a very strange and unusual sight. Along Presley hill, just to the west, the greatly tilted beds of this formation have a thickness of from 30 to 40 feet. At the bluff east of Graydon Springs, on the Sac, these beds have a thickness of about 75 feet. On the section from Morrisville south to the Sac, on the southern slope of the Morrisville Brighton fold, is found 25 feet of Hannibal sandstone overlying 25 feet of the shales. This is one of the best points in the area for the study of the Kinderhook beds. The rounded hills and knobs, with their frequent terraces, are a characteristic feature peculiar to this horizon. At the Thorp drill-well (Tp. 32 N., R. XXII W., Sec. 36), about 70 feet of the shales were passed through, the sandstone being either very thin or wanting. At the Newton mound (Tp. 31 N., R. XXI W., Sec. 1, center of Ne. qr.), there are 50 feet of sandstone and shales, mainly sandstones.

The Hannibal formation is, in a few places, ore bearing, as along Pierson creek. It is, however, usually too thin to hold large deposits of ore. As regards soil, where the material is suitably mixed with the superincumbent beds, the land is very moist and fertile, but if there is too much sand the opposite conditions prevail. Some of the finest farms of this area are underlaid by the Kinderhook beds. The shales frequently decompose into a clay which is deserving of a wider use. A

pottery has been established north of Bolivar, in Polk county. Swallow states that the middle beds often pass into an impure magnesian limestone which has every appearance of being suitable for the making of hydraulic cement. As a building material, the sandstone is largely used by the residents for chimneys, and for stepping stones and walls. It breaks easily into large cuboidal blocks, the slopes and terraces being frequently covered with them, so that the stone is comparatively easy to handle and work. It is quite durable. The shales are usually too soft and decomposable for building purposes, though in a few places, as at the Gilmore mill on the Finley, at the Southworth quarry (Tp. 27 N., R. XX W., Sec. 15) and at the Holman quarry (Tp. 30 N., R. XXI W., Sec. 28) the lower beds are much more indurated and durable, breaking readily into rather thin slabs. At these three points quarries have been opened and considerable material has been shipped to Springfield where it is used for curbing and flagging. Springs in this formation are weak, and their temperature much higher than those of other formations. They are always poor, and frequently so charged with mineral matter as to be unwholesome and disagreeable to the taste. Three miles south of Pleasant Hope, on the Springfield road, is a well on the Cochran farm which is an extreme example. The water being purgative in its effects, is most disagreeable to all who use it. This is undoubtedly due to the presence of the magnesian sulphate (epsom salt) which it contains. The shales have a large amount of iron pyrites and magnesium carbonate. The former decomposing, produces sulphuric acid, which reacts upon the magnesium carbonate, sets free the carbonic dioxide, and produces magnesium sulphate.

As a rule, fossils are rare in the sandstones, only the sea weed markings, so-called worm borings and the cauda-galli being observable. A few specimens of a Terebratula have been found in the outcroppings below the Headlee spring (Tp. 31 N., R. XXII W., Sec. 34). In the northern half of the area, particularly at King Butte (Tp. 31 N., R. XXII W., Sec. 23) the shales contain many fossils, and it is noticed that they are

all small forms, especially brachiopods and gasteropods, indicating that the condition of the water was unfavorable for their development. On the clay resulting from the decomposition of the shales, the fossils are exposed and scattered on the surfaces of the slopes, terraces and gullies. A few other localities for fossils have been discovered, and it is not unlikely that rich deposits may be found in other outcroppings in the northern part of the area.

In the southern half of the area, with the exception of a few brachiopods and the caudi-galli markings, which everywhere cover the surfaces of the shales and sandstones, no fossils have been found. The localities where the brachiopods were obtained are at Pierson creek, and at the Holman quarry. Slabs of rock from the latter locality are frequently covered with the sea-weed-like markings which are an inch or more in diameter, and sometimes several feet in length. They may be seen in many of the curbings and cross-walks of the city of Springfield.

Chouteau Limestone. While varying structurally at different points, this formation possesses certain general lithological characteristics by which it may be easily recognized. It is fine-grained, compact, heavily bedded, buff to yellow in color, frequently slightly arenaceous, much softer in the bed than when exposed to the air, and weathers badly, leaving the surface with deep, irregular grooves and prominent rounded ridges and points. It is unfortunate for the geologist that there are intercalated layers of similar color, structure and general appearance in both the Upper and Lower Burlington limestones. Swallow,* in his geological map, maps this formation as outcropping along the James river in Tp. 28 N., R. XXII W., Sec. 36, Ne. qr., and for a number of miles down the river; but this has been proved to be the Chouteau-like layer in the lower beds of the Upper Burlington limestone. A number of other points where the Chouteau-like layer outcrops in these upper

*Geo. Rept. Country along line of Southwestern Branch of Pacific Railroad, 1859.

formations, will be mentioned in the description of the Upper and Lower Burlington limestones.

The variation in structural characteristics which has already been mentioned in speaking of the preceding formation, is equally possessed by the Chouteau, a gradual transition from shallow waters to deeper sea deposits being well exemplified in this formation.

In passing from the Springfield fold, either to the north or south, especially in the latter direction, and on the southern slope of the Morrisville-Brighton fold, a few typical sections will be given illustrating these transition stages.

On the northern slope of the Springfield fold, in the northwestern sections of Tp. 29 N., R. XXI W., the south fork of Dry Sac cuts through the Lower Burlington into the Chouteau, as will be seen by reference to the map.

In Tp. 29 N., R. XXI W., Sec. 3, Nw. qr., the following section is obtained:

	Feet.
2. Lower Burlington (slope)	30
1. Chouteau	30

About 300 feet to the east, a Hannibal sandstone juncture with Chouteau is exhibited in the bank of a small stream, and the barometer indicates a thickness of 30 feet for the latter. Just beyond, a fine large spring issues from a cave-like fissure in the bluff. This was, undoubtedly, at one time, a Chouteau-Hannibal contact spring, as is evinced by the broken and tumbled blocks of Chouteau around the spring. The rock is here a heavy-bedded, hard and compact, yellowish to buff limestone. It is quite uniform in texture, and contains miniature crystals of calcite, and occasionally minute crystals of pyrites. It is here, as elsewhere, an impure, arenaceous, magnesian limestone.

At Gibson spring, near the head of Pierson creek, the following section was obtained:

	Feet.
2. Lower Burlington chert	20
1. Chouteau	30

The lithological characteristics are similar to those in the section given above.

Weller obtained the following section down the bluff to the James river, near Compton (Tp. 29 N., R. XIX W.):

		Feet.
6.	Chert	20
5.	Upper Burlington limestone	35
4.	Burlington chert and limestone	45
3.	Chouteau	40
2.	Hannibal sandstone and shale	38
1.	Louisiana limestone and Devonian (exposed)	22

This gives the maximum thickness of the Chouteau, as far as observed in the area. It should be noted here that these three sections, taken on the slopes and near the axis of the Springfield fold, give a hard, compact and heavy-bedded, sandy, magnesian limestone, and the contact between the Chouteau and the Hannibal sandstone below is well defined, while, in the sections following, running from west to east, and southward a few miles from the section just given, the contact is obscure, and the rocks become softer, more earthy and shaly, the sandstone of the Hannibal being almost wholly absent. At the Pierson Creek mines, the following section is obtained:

		Feet.
4	Lower Burlington chert and limestone	60
3	Chouteau limestone	30
2.	Hannibal shales	40
1.	Devonian	10

In this section advantage is taken of a shaft 65 feet deep at the foot of the bluff, which penetrates through the Phelps sandstone of the Devonian, the Louisiana being, apparently, wanting at this point. The Chouteau here is quite uniform in texture, more earthy and darker colored, and it graduates less abruptly into the Hannibal shales, the Hannibal sandstone being entirely absent.

In the northwestern part of Tp. 29 N., R. XX W., Sec. 6, on the west bank of the James river, where the Rockbridge road crosses the iron bridge, 40 feet of Lower Burlington and 30 feet of Chouteau are found in the bluff, the juncture between the Chouteau and the Hannibal shales being in the bed of the stream, and the James flowing at this point upon the upper beds of the Hannibal shale, the sandstone being almost wholly absent.

At the Peacher spring, near Henderson, four distinct strata were noted composing the Chouteau. The upper bed is in thin layers, about four feet in thickness, made up of soft, easily crushed, yellow, fine-grained, arenaceous, impure magnesian limestone. The second layer about six feet in thickness, is a bluish gray to yellowish shale, somewhat resembling the Lower Burlington in color and texture, but is rather fissile, hard, fine-grained, more compact, light colored, and contains occasionally small interspersed crystals of calcite. The next layer of ten feet is more heavily bedded and darker yellow in color. It contains some calcite crystals and imbedded in it are also found lenticular masses of chert resembling those of the upper Burlington, but more regularly arranged in layers. One very striking peculiarity is the presence of rather large crystals of calcite embedded in the lenticular masses of chert, seeming to surround cavities of soft, decomposed, ferruginous material. Though this chert is hard, it is very impure and contains a large amount of magnesia and lime. Some of it near the bottom of the layer is almost like the rock proper in texture, color and composition. None of the masses exceed one foot in length and three inches in diameter and the majority of them are much smaller. The fourth or lowest layer is from ten to twelve feet thick, is heavily bedded, very soft, finely granular, crushing easily into a sandy substance of a dark yellowish color. There are a few small cavities filled with soft, ferruginous matter. The weathering of this stratum along the bluff and the alternation of the softer and harder layers gives the rock a laminated appearance. The thin laminae pass so gradually into the shale below that it is often difficult to determine just at what horizon the distinctive lithological characteristics of the Chouteau end and those of the Hannibal begin.

Nearly due east of the Peacher spring, in Tp. 28 N., R. XIX W., Sec. 10, Ne. qr., is the Sheridan spring. It rises from a crevice in a bluff on the north side of the southern branch of Panther creek. About 30 feet of Chouteau overlies the shales over which the stream runs. The distinction into four beds somewhat similar to those at the Peacher spring is noted. The

lower bed is harder in the upper part, and becomes very soft where it graduates into the shales below. The dip of the strata here is strongly to the west and south. Attention is again called to the insensible gradation of the Chouteau into the shales. About 8 feet of the shales outcrop here. These disintegrate much more rapidly, leaving the Chouteau overhanging the Hannibal strata, causing an undermining of the Chouteau, which breaks off into large blocks and falls into the stream below.

Sections obtained in the southern limit of the district show a decided thinning out of the Chouteau, and an increase in the thickness of the Devonian beds and the First Magnesian limestone. At the Southworth, formerly Johnson, quarry (Tp. 27 N., R. XX W., Sec. 15, Ne. ¼ of Ne. qr.), 4 miles northwest of Sparta, the Chouteau thins out to about 6 inches, and from this point to the western limit of the district it is quite attenuated.

The most typical example is found in Tp. 27 N., R. XXII W., Sec. 36. In a bluff on the north side of the Finley, at the Gilmore mill, is found an outcrop near the water's edge of about 6 feet of Chouteau overlying the Hannibal shale. Here the rock is very friable, soft, earthy and dark yellow in color. It weathers in a most extraordinary manner, decomposing rapidly into a yellowish, sticky clay, which imbeds pisolitic or agglutinated nutmeg-shaped masses of harder material, resembling, in color, the original rock. An apparent gradual transition of the chert is found here, though entirely unlike that which was described at the Peacher spring.

The study of the chert in the Chouteau will, it is believed, throw some light upon the abstruse problem of the origin of chert, a subject that should be more carefully investigated.

Northeast of the Gilmore mill, at Linden, in the southeastern part of Tp. 27 N., R. XX W., Sec. 9, are found about 15 feet of Chouteau resting upon the shales.

In the southeastern corner of Tp. 27 N., R. XIX W., thin beds of from 6 to 8 feet of Chouteau are found in the bluffs along the banks of Lost creek. The rock is slightly harder

than at the Gilmore mill, and is only occasionally seen through the slope of Lower Burlington chert.

To the west of Gilmore mill, the last outcroppings found are along the James river in Tp. 27 N., R. XIX W. In a draw, in Tp. 27 N., R. XXI W., Sec. 29, where the shafts of the Delaware mining company are situated, but ten feet of Chouteau are found. The well-section at the Metropolitan power-house, in the city of Springfield, gives about 30 feet of Chouteau at a depth of 210 feet.

Outcroppings of the Chouteau in the north half of the area are mainly confined to the slopes of the synclinal valley that stretches from Northview to Graydon Springs. Along this stretch of country, particularly on the southern slope of the Graydon-Northview anticline, numerous faults have elevated this formation above its proper position. North of Strafford, the beds are either greatly denuded or very thin. At the Lamb spring, northeast of the station, a section of about six feet of Chouteau is shown; but northwestward, along the Sac, which flows nearly through the center of Franklin township, the Chouteau rapidly thickens. East of the Springfield and Fair Grove road, in Tp. 30 N., R. XXI W., Sec. 23, in the bluff which divides the Sac, there is an interesting section. On the south side it is quite precipitous with a height of about 70 feet above the stream, of which 25 feet is the typical heavily bedded Chouteau, overlying about 40 feet of Hannibal sandstone and shale. East and west of this point the Chouteau outcrops on both sides of the stream forming, in places, mural bluffs. On the north side of the Sac, on the Beckner place (Tp. 23 N., R. XXX W., Sec. 21), a good section is shown 40 feet above the bed of the stream, the lower 10 feet of the Chouteau outcropping in a vertical bench, the bottom layers being thin, soft and shaly, the transition beds to the Hannibal. Above these the rock is heavily bedded and fossiliferous, exhibiting the usual irregular conchoidal weathering. Above the bench and underlying the Lower Burlington chert which caps the hill there is a slope of

10 feet of irregular thin layers, alternating with chert. One mile to the west at the Hunt mill (Tp. 30 N., R. XXI W., Sec. 32), is one of the most picturesque points in the township, and, in many respects, one of the best exposures of the Chouteau. A stream issues from a small cave at the head of a narrow gorge midway up the bluff. The water is conveyed for several hundred feet along the edge of the bluff by a race-way to the mill-flume. The spring has evidently cut back the gorge several hundred feet from the Sac by eroding and undermining the softer shales beneath. The following section is shown at this point:

		Feet.
1.	Limestone, lower Burlington	40
3.	Limestone, Chouteau, dark yellow, heavily bedded, containing numerous small masses of calcite and in the lower layers frequently balls or nodules of pyrites and a number of fossils	25
2.	Shale, Hannibal	40
1.	Slope to bed of Sac	10

Just west of this section the Springfield and Buffalo road skirts a high, beetling bluff capped by Chouteau. Northward, on the Buffalo road the first outcroppings of the Chouteau are along the line of faulting on the Graydon-Northview anticline near Edmiston hill (Tp. 31 N., R. XXI W., Sec. 35), but it is difficult to obtain a good section as the faulting has so crushed the beds as to make them an easy prey to the elements, and only a few feet are exposed. For several miles southeastward along this faulting, no good sections are found except at Lamb spring (Tp. 30 N., R. XX W., Sec. 24), where the rock thins out to about 6 feet. The Chouteau thins out decidedly in this direction, while the Hannibal thickens correspondingly. Similar conditions are found northeast of Edmiston hill, on the Buffalo road, where the numerous mounds in the neighborhood give sections of the Kinderhook beds.

On the Ebenezer and Marshfied road, just west of the crossing of the Buffalo road, several springs issue from the foot of the bluff on the Headlee farm (Tp. 30., R. XXI W., Sec. 3, Nw. qr.). The Chouteau, with typical lithological characters, is exposed to a heighth of 35 feet. Northeastward, outcrops along Sims

branch and the Dry Sac indicate considerable variation in thickness, but a constant tendency towards an increase in the Hannibal, and a decrease in the Chouteau. This is shown at a number of places, particularly in the bluff at the junction of King branch and Dry Sac, where it is 15 feet thick. On the hill toward the Sac river (Tp. 30 N., R. XXII W., Sec. 9), on the Cave Spring and Ebenezer road, only 10 feet of Chouteau are found. A short distance south of Morrisville, on the Springfield road, 12 feet of the Chouteau overlie 50 feet of Hannibal sandstones and shales; and at the Thorp drill-well, west of Brighton, the thickness of the Chouteau is about 30 feet, with over 70 feet of Hannibal.

The Chouteau is too thin to form much of an ore horizon. Where there has been opportunity for studying the fissues that pass through it, very little ore has been found. Its structure seems eminently unfavorable for the accumulation of an ore body. As a building material, some of the harder arenaceous beds would probably justify a more general use. Its color is handsome, and it presents a strong contrast to the Upper Burlington and Magnesian limestones that are so generally used. It will undoubtedly replace some of the trimmings that are now imported at considerable expense.

There are but few quarries of this stone. One is in Tp. 29 N., R. XIX W., Sec. 7, where a small amount has been taken out; and another is the Peacher Springs quarry, which is used by the village of Henderson and vicinity for house foundations, chimneys and other purposes. On the James river, south of the railroad bridge (Tp. 29 N., R. XX W., Sec. 32), a quarry has been opened for a great many years, stones taken from which are now standing in the pillars of the Court House at Springfield, where they have been exposed to wind and weather, but are marred only by the vandalism of man. The same stone has also been used in the piers of railroad and other bridges. It is far more durable as a building stone than one would expect from the weathering seen in the bluffs. It is easily quarried, and handsome, and deserves a much wider use. The clays resulting from decomposition of some of the argillaceous beds

might be used in brick-making. Ordinarily, the soil resulting from this formation is rich, and forms some fine farming lands.

The scenery produced by the Kinderhook beds is so striking that a little experience enables one to recognize them at some distance. Rounded hills, with gentle slopes and terraces, are the characteristic features which give a very pleasing effect to the country. On wild land, the sumac grows luxuriantly along these terraces. Mounds and low buttes frequently occur from the weathering of the softer shales beneath. Quite a striking series of these rounded mounds is seen along the Graydon-Northview anticline, north of Strafford, in T. 30 N., R. XX W.

Owing to the fact that these deposits represent the sediments dropped by turbid waters, fossils are not very abundant. In the argillaceous and calcareous beds, however, are occasionally found some well-preserved forms, while they are rarer in the arenaceous beds, and generally in the form of casts.

The best points for collecting will be found in the outcrops on Sac river, in Tp. 30 N., R. XXI W., between the Holman quarry on the Springfield and Fair Grove road, and Hunt's mill near the Buffalo road—especially the latter. A few imperfect brachiopods were found in Tp. 27 N., R. XXI W., Sec. 3 Nw. qr.

Augusta Limestone. The term Augusta is applied to a succession of limestones found in southwestern Missouri which heretofore have had local names applied to them but invariably without definition. The title covers what in the northeastern part of the state and adjoining country was formerly subdivided into five separate formations: (1) Lower Burlington limestone, (2) Upper Burlington limestone, (3) Keokuk limestone, (4) Geode bed, and (5) Warsaw shales. The advisability of uniting the first three under a single head was pointed out as long ago as 1889,* and subsequently† the name Osage was proposed. Soon afterwards,‡ in southeastern Iowa and

*Am. Jour. Sci. (3), vol. XXXVIII, p. 193, 1889.
†U. S. Geol. Sur., Bull. 80, p. 109, 1899.
‡Iowa Geol. Sur., vol. I, p. 59, 1893.

northeastern Missouri, careful examination of the lower Carboniferous beds and an extended study of the fossils collected at the various horizons showed beyond all doubt that the "Geode" and the typical Warsaw beds were properly a part of the Keokuk formation, and all five members were united under a single term Augusta.

The title Augusta has only recently* been applied to the rocks in southwest Missouri. As this is so far from the original locality in southeastern Iowa, the data for such determinations may be summarized. "In order that the sections in southwestern Missouri might be accurately correlated with the typical localities as a basis for future detailed work, the lower Carboniferous strata were carefully traced from Iowa southward along the eastern border of the state; all the original localities were examined in detail, and full collections of fossils made. From northeastern Missouri the strata were similarly traced across the state into the southwest. The Kinderhook, Upper Burlington and Lower Burlington limestones were found to extend the entire distance with almost no lithological or faunal change. But with the Keokuk and higher formations of the lower Carboniferous, which are so well displayed in southeastern Iowa, some startling facts developed in progressing southwestward. After passing the Missouri river, where at Boonville, these rocks occur with abundant and characteristic fossils, the Keokuk beds soon vanished. At Sedalia, and for 50 miles beyond, no Keokuk or higher beds of the lower Carboniferous limestone appeared to be exposed, and the coal measures rested directly upon the Burlington. This was, indeed, clearly demonstrated nearly a quarter of a century ago. It is at this part of its southwestern extension in Pettis, Benton and St. Clair counties that the lower Carboniferous zone abruptly narrows from a width of 75 miles on the north and south to less than a dozen miles. At some points the belt is reduced to a mere thread, as it were, with only a limited vertical exposure disclosed by some stream, the Chouteau limestone being below and the coal measures in the bluffs above.

*Missouri Geol. Sur., vol. IV., p. 59, 1894.

Such a place was at the Osage river. Repeated search and rather extensive collections of fossils from the various levels failed to disclose anything of the lower Carboniferous above the Burlington. Probably the feature which most disguises the lower Carboniferous rocks of southwestern Missouri is the great prevalence of chert; and in the absence of a careful examination of the fossils much difficulty has been encountered in the interpretation of the stratigraphical problems presented."*

Still more recently† it has been urged that the term Osage is the proper name to apply to the middle Mississippian strata of the state. But the objections to this name are many. The Osage river, from which the term was derived, flows for the greater part of its course through limestones of Silurian age. The upper portion of the stream traverses only the shales of the Coal Measures. Only a very small portion touches the Lower Carboniferous at all; and then only the inferior portion of the Burlington limestone. The "Osage country," as widely known since the first settlement, applies distinctly to the lower waters of the stream. Recent visits have disclosed no Keokuk whatever at the place in question. One of the chief reasons for proposing Osage was that the beds of southwestern Missouri were thought to contain a mingling of faunas of both Burlington and Keokuk beds. The Kinderhook, Burlington and Keokuk beds are as sharply contrasted lithologically, faunally and stratigraphically as in southeastern Iowa. From the foregoing it would seem that the "Osage" formation, at its typical locality is practically co-extensive, and therefore synonymus, with the Burlington limestone.

Weller‡ has lately set forth arguments to show that the name ascribed has priority over that of Augusta, but in doing this it is very clear that the question is entirely misunderstood. It is true that the former was proposed before the latter; but this does not necessarily indicate that it has priority. The

*American Geologist, vol. XVI, pp. 86-98, 1895.

†Am. Jour. Sci. (3), vol. XLIX, p. 185, 1895.

‡Am. Jour. Sci. (3), vol. XLIX, p. 185, 1895.

two terms are not coextensive, as is urged. In reality the first embraces only the lower three members of the second. There is still another point mentioned by Weller as a reason for adopting the name Osage. It is the alleged presence of the Keokuk at Springfield ; and lists of fossils are given to show that the Keokuk fauna exists there. All of the localities at which Keokuk forms were claimed to have been found have recently been visited in company with one who is thoroughly familiar with the typical Keokuk in Iowa, and not a single trace of a fossil was found that could be referred to that horizon. Not a species occurred that ever belonged to the transition beds between the Keokuk and Upper Burlington ; all were characteristic of the latter alone. Careful revision of the list of fossils given as belonging to the typical Keokuk will show that all the former should be referred to the typical Burlington species.

Lower Burlington Limestone. Next to the upper division of the Augusta of this region, this formation has the widest distribution of any rock in the area. The dip of the strata to the southwest buries it beneath the upper member in the western tier of townships. It reaches a maximum thickness of a little over 100 feet in the eastern and southeastern part of this region, thinning out and eventually disappearing toward the north. It averages about 70 feet in thickness. It is best exposed around Rogersville, in Benton township, Webster county. The formation may well be separated into three divisions.

The upper beds of the Lower Burlington are made up of from 5 to 20 feet of yellowish-white, very hard chert, which breaks with a conchodial or splinterly fracture, some fragments being as sharp as a knife blade. This chert is apparently non-fossiliferous. It sometimes has a bluish cast, but is more usually pure white with an external yellow tinge, due to iron. The amount of chert increases toward the south from Springfield. One section in northern Arkansas gives 165 feet of almost solid chert, darker color, but still possessing the great hardness and peculiar fracture which characterizes the white variety. The Burlington chert predominates south of the area,

on the flanks of the Ozark uplift, in as pronounced a manner as does the Upper Burlington near the center of the uplift. Most of the ridges in the southern tier of counties in southwestern Missouri and in northern Arkansas are broken Burlington cherts, while the streams cut into the Magnesian limestone. This almost indestructable chert covers the surface of the Burlington, and it slopes in the southern half of this area in such a manner as, in many cases, to bury the Chouteau, thus making it very difficult to obtain sections in this horizon, or to properly mark out the extent of the last named formation. It is, however, in general, a very valuable lithological characteristic, and it again illustrates, in its percentage increase to the south, the deeper ocean in that direction. Its abundance at the close of the epoch which marked the deposit of the Lower Burlington limestone indicates deep water and the quiet conditions that preceded the elevation producing the unconformity that exists between this formation and the Upper Burlington in this area, and which helped to bring about conditions favorable for the abundance of life which made the fine limestones of the Upper Burlington.

In a low bluff on the east side of the James river, south of the Gibson ford, alternating beds of limestone from 6 to 18 inches in thickness outcrop in ledges which lithologically resemble Chouteau. The upper layers of these beds are a light brownish yellow, the lower being darker, more Chouteau-like, and carrying minute particles of calcite. There are 20 feet of the Chouteau-like beds which overlie about the same thickness of alternating beds of this shaly, nodular chert, with softer crinoidal layers and the typical hard blue limestone. It was somewhat difficult, for want of paleontological evidence, to decide whether this represented the Chouteau-like layer of the Upper Burlington, resting on the Lower Burlington, or whether it was a distinct bed of similar characteristics belonging to the latter. Evidence obtained from the outcroppings above and below this point on the river rendered the latter view more probable. This same peculiar structure has been noted at several other places. As far as investigated, this layer in-

creases toward the south, and it is quite probable that it may be the northern equivalent, in the Lower Burlington, of the marble beds which underlie the massive chert deposits of that formation in the northern part of Arkansas, and in the southern tier of counties in Missouri.

The basal portion of the lower Burlington is made up of a heavily bedded, bluish or slate colored, fine-grained, very hard limestone which is often interspersed with lenticular masses of chert in the north, and which, toward the south, as seen in the little bluff just north of Ozark, becomes mixed with the lime in the most extraordinary manner. The chert has the appearance of having been squeezed, laterally, in great rolls into the thin layers of limestone. At the Robberson mill, near the mouth of Parched Corn creek, is a succession of numerous alternating beds of chert and limestone only a few inches in thickness. A still finer example of these alternating beds is found on the Carter farm, 1 mile southeast of Linden (Tp. 27 N., R. XX W). Here is a bold vertical bluff about 50 feet in height, made up, mainly, of thin layers of limestone and chert so as to resemble a wall of masonry. The proportion of chert in the lower beds presents the same increase as is noted in the upper beds.

The Metropolitan well-section at Springfield gives a thickness of 70 feet for the Lower Burlington limestone. To the east, Pierson creek, along the greater part of its course, cuts through the upper member. In Taylor township (Tp. 29 N., R. XX W.), on account of the southwesterly dip of the strata, the same rock occurs as a penumbral margin to the upper division which forms the summits of the hills on both sides of the James river. The greater part of the southern tier of sections is also covered by it. In Dallas township, Webster county, the Burlington chert forms the surface rock of the entire district, with the exception of the valleys of the James river and Panther creek. Good sections of the limestones are obtained along the bluffs on the first-named stream, especially one-half mile below Ingram mill, in Clay township. Here the Burlington is exposed in the bed of the stream to a height of

70 feet above the Chouteau. The upper beds here are blue, compact, very hard, and break with conchoidal fracture. The middle layers are softer, and in places decompose, and undermine the upper layers. Below is a hard, more heavily bedded, compact and dark blue limestone, which breaks with a splintery, conchoidal fracture.

Nearly the whole of the northwest corner of Washington township is underlaid by this limestone, forming a continuation of the great lower Burlington plateau that stretches north and south through the adjoining townships.

Passing southward, in Tp. 29 N., R. XIX W., in Christian county, in the southeastern corner of the area, is found a more broken country, which the abundance of Burlington chert has caused to be largely left to timber. The scenery in this and the adjoining township to the west, along the Finley and its tributaries, is very beautiful. The high ridges in the north half of the township are, as before stated, covered with Lower Burlington chert, while to the south, and especially to the southeast, the country is very much broken and rugged, with high cherty ridges and narrow, deep valleys running down toward Swan creek. The gorges running down to Finley and Petelo (shot-pouch) creeks are, many of them, very abrupt, narrow, and with precipitous sides, making, perhaps, the wildest and most picturesque scenery in the whole area. The hard, cherty Burlington forms mural bluffs and escarpments of great beauty. The view from the bluff on the north side of Finley (Tp. 27 N., R. XIX W., Sec. 15), looking eastward up the stream, is remarkably fine. This bluff is about 150 feet high, with an exposure of about 65 feet of Lower Burlington. At Haydon spring (Tp. 27 N., R. XIX W., Sec. 6) is another fine exposure of Lower Burlington. This spring is situated at the head of a very narrow canyon, about a quarter of a mile west of Petelo creek. The bluffs rise to a height of about 150 feet at the mouth of the canyon, decreasing to about 90 feet at its head, where is situated the lower Burlington-Chouteau contact spring. At the head of the canyon is a fine exposure of Lower Burlington 60 feet thick. In Tp. 27 N., R. XX W., on the

north bank of Finley, the Lower Burlington forms a fine escarpment for several miles. Another grand example of these narrow canyons is found near the middle of Tp. 27 N., R. XX W., Sec. 13, to the east of the Rogersville and Sparta road, on the Johnson farm. Here a narrow gorge 130 feet deep and about 200 feet wide cuts into the plateau and terminates in a vertical wall of Burlington. At this place the following section is obtained:

		Feet.
5.	Upper Burlington limestone and chert	80
4.	Lower Burlington	60
3.	Chouteau	10
2.	Hannibal shale	10
1.	Slope	20

In Tp. 27 N., R. XXI W., Secs. 13 and 14, is found a continuation of the bluffs on the north side of the Finley. Starting abruptly from the water's edge with the heavy-bedded limestone, they rise to a height of from 50 to 70 feet, and follow the tortuous course of the river for several miles.

The heavy chert deposits of the upper beds of the Lower Burlington increase in the above-mentioned township, and the soil, where the chert is exposed, is generally poor. The middle beds in this township differ widely in structural characteristics from the outcrops in any of the other townships, varying from heavy-bedded limestone in the north, and from the numerous thin, alternating layers of chert and limestone in the east, to the strange mixture of chert and limestone shown in the following examples:

Just below the mill in Tp. 27 N., R. XX W., Sec. 7, Ne. qr., on Parched Corn creek, about 12 ft. of Burlington outcrops, and is made up of very thin layers of compact, hard, fine-grained bluish limestone, alternating with chert in rounded, curved, cylindrical masses, squeezed into the limestone in the peculiar form before described. This peculiar structure is, perhaps, better studied in a low hill in section 23, between the town of Ozark and the railroad, where is found a long, low hill about 40 ft. high cut into by erosion on both sides, so as to well expose the north and south sides and east end. The surface and a portion of the slope is covered with the charac-

teristic Lower Burlington chert, and the middle layer beautifully represents the peculiar structure of chert described above, and is somewhat agatized. The lower two or three feet change abruptly into a fine-grained, very soft, and easily decomposed, thin, shaly limestone, which has never been seen at any other point, and which contains quite a number of fossils. The thickness of the Lower Burlington in this township ranges from 70 to 100 feet.

In Tp. 28 N., R. XXII W., near the Noland mill, there are from 5 to 12 feet of Lower Burlington chert capping 20 feet of heavily bedded limestone. Along the James river, the Burlington ranges in thickness from 40 to 50 feet.

In Brookline township, Tyrrell, Robinson and Wilson creeks do not cut through the Lower Burlington, but run for miles through the upper and middle beds. The more calcareous and less cherty structure of the middle beds is here emphasized. To the northwest, the chert deposits appear to thin out considerably. Thin, alternating layers of typical Burlington chert and limestone occur, the latter slightly predominating, and the former being slightly softer than usual. The layers are extremely irregular, thickening, thinning, and penetrating one another. A heavy bed of Lower Burlington chert evidently overlies this deposit. No complete section is obtained.

North of Springfield, in Franklin and Robberson townships, the Sac and the South Dry Sac cut down into the middle beds of the Lower Burlington, which is evidently much thinner here. In Tp. 29 N., R. XXII W., where the Doling Park-Ebenezer road crosses the Doling Park branch, a small outcropping of Lower Burlington is exposed on the south side of the road, having been elevated by the McCracken fault.

In the vicinity of Graydon Springs, in the northwest corner of the area, this formation seems to have entirely disappeared. The same is true at the Thorp drill-well (Tp. 32 N., R. XXII W., Sec. 36), and no outcroppings outside of the area to the north are known. South of Morrisville, on the Springfield road, about 12 feet of Burlington is represented. At

the Headlee Place (Tp. 31 N., R. XXI W., Sec. 34), it has a thickness of probably from 35 to 40 feet. To the north, in this township, it becomes cherty, and rapidly thins out. On Presley hill, along the faulting, but a little chert debris was found. In the splendid bluff at the juncture of Dry Sac and King branch, there is an outcropping of 20 feet. At the spring on the McGuire farm (Tp. 32 N., R. XXII W., Sec. 34), but 12 feet of the Burlington are exposed.

Owing to the indestructibility of the chert, and the excessive hardness of the limestone, this formation presents the most unfavorable conditions possible for the deposition and accummulation of an ore-body; hence the almost total absence of ores in paying quantities in this formation throughout the southwest. At the Pierson Creek mines a vein fissure extends up into the Burlington, but the ore is so scant as to render that part of the mine valueless. At the Lang diggings, just over the line of the area, south of Ozark, a narrow vein is exposed in the bluff and extends through the whole thickness of the formation, up into the Upper Burlington above. The amount of ore is so small as not to encourage mining, but it is quite promising both above and below this formation.

This may be pronounced a barren horizon for ore in southwest Missouri, when the above lithological conditions prevail.

As a building stone, this rock can never be so valuable as it is in the northern part of the state. Usually it breaks in an irregular manner, and contains much chert. There is one point in its favor which, strange to say, has been almost wholly overlooked. Everyone who has driven over the ridge roads in the southern counties must have been impressed with the way in which the chert packs down and forms a natural macadam roadway. As a material for macadamizing, nothing could be finer than this chert, and its economic value in this respect should be emphasized. The Lower Burlington rock is not utilized for burning into lime, though it is extensively used for its manufacture outside of the area, in localities where the rock is less silicious.

Between the Upper and Lower Burlington there is considerable unconformity. At or near their contact are the finest and largest springs in this district. The porous, coarse-grained, cavernous Upper Burlington, with its numerous sink holes, forms a fine reservoir for percolating waters, which, meeting the compact Lower Burlington below, burst out as fine, cold springs.

Throughout this region, but few fossils have been found in this formation. The best locality, and one that has proved a rich one for the collector, is that before referred to in the shaly beds at the foot of the bluff between the town of Ozark and the railroad. Some fine specimens have been obtained at this point. One good locality, discovered by Mr. Stuart Weller, may be mentioned, in Tp. 29, R. XXI, Sec. 14, Sw. ¼ of Sw. qr., where some good specimens were obtained in a dry run in a shaly layer of the Lower Burlington. Rarely, the lower, heavy-bedded limestone, upon weathering, exposes a few crinoid stems, a striking contrast to the magnificent crinoids found in this formation in Iowa and Indiana. It is probable that the abundance of silica in the water was unfavorable for crinoids. When the calcareous conditions returned, in the upper Burlington, they became abundant.

The following fossils have been found in the Lower Burlington in Greene county, those marked * being given on the authority of Mr. Weller:

Spirifer forbesii.
Spirifer suborbicularis, Hall.
Spirifer biplicatus, Hall.
Spirifer marionensis, Shumard.
Spirifer grimesi, Hall.
**Spirifer lineata*, Martin.
Productus flemingii.
Productus burlingtonensis, Hall.
Productus punctatus, Martin.
**Productus laevicostus*, White.
Productus sp.
**Orthis burlingtonensis*, Hall.
**Terebratula burlingtonensis*, White.
**Athyris lamellosa*, L'Evelle.
**Chonetes illinoiensis*, Worthen.
**Derbyia keokuk*, Hall.
**Entolium circulus*, Shumard.

**Phanerotinus paradoxus*, Winchell.
Loxonema sp.
Platyceras sp.
Murchisonia sp.

Upper Burlington Limestone. The most important formation in the district is the upper division of the Burlington which covers almost its entire southwestern half. The upper beds are well shown in many outcroppings and in the large quarries, railroad cuts and bluffs around Springfield. It very likely reaches its maximum thickness of over 200 feet here and in Washington township, thinning out and becoming more or less modified toward the southeast. This alteration is due partly to the dip of the rocks and partly to denudation. The upper portion, in nearly all sections that have been obtained, is made up of chert or thinly bedded, alternating layers of shaly limestone and chert. Where the shaly limestone has predominated and denudation has acted upon it, as in the headwaters of streams and around springs, the surface of the ground is covered with very thin, irregular slabs which are frequently used for walls. These limestone beds are more compact in structure than those below, and occasionally they are somewhat oolitic. Where the cherty layers predominate, the original bedding is frequently almost wholly lost by disintegration and denudation, leaving, in many places, great beds of fragmental chert and residual clay, where the drainage has been such as to carry away the more soluble calcareous material. This is well exhibited along the bluffs of the James river and some of its tributaries. In other cases, where the surface drainage has been less vigorous, there is a very peculiar stratification exhibiting wave-like folds. The limestone has been partially decomposed and washed out, causing the chert, which was originally bedded in a horizontal manner, to break down and leave short abrupt folds from 5 to 10 feet across imbedded in the red ferruginous clays. At Springfield the chert is rich in fossil remains. Where the drainage is slight, the chert is left mixed with the residual clay both from the limestone belonging to it and from the formerly overlying beds of ferruginous sandstone in such a manner as to form a wet hard-

pan soil, making the post-oak flats so common in many townships, and especially just south of the Graydon-Northview anticline.

Microscopical sections of the chert from several localities show an abundance of rhizopod remains. The lenticular form in which the chert is found and the tendency toward distribution in layers is strikingly characteristic of the formation. The horizontal diameter of the lenticular masses is several times the vertical dimension. Frequently lenticular masses are filled in the center with soft calcareous matter. Occasionally they are hollow and in some cases they decompose into a fine, white, tripoli-like clay. This characteristic is strikingly exhibited by the chert of Seneca, Mo. The chert throughout the whole formation is usually soft, owing to its calcareous nature. It is much less compact than the chert of other formations, very ferruginous, fossiliferous and easily decomposable. These striking features are the guide in southwest Missouri that makes this chert a geological landmark. This is particularly true of all the area, except in the extreme southwest, where it gradually becomes harder, less calcareous, less ferruginous, and carries fewer fossils. When masses of this chert are broken into two pieces, the parts, when replaced, do not exactly fit, indicating a molecular tension or strain.

The upper beds of this formation weather in such a way as to expose innumerable sections of crinoid stems. This is well shown in the quarries and railroad cuts in the vicinity of Springfield. The limestone of this horizon is very pure, coarse-grained, but rarely compact. It is usually fossiliferous, decidedly more so than any of the other formations. It varies in color from white to grey. Crystallites or suture joints are common in some of the upper beds. They form a slightly waving horizontal band in the face of the exposure, being generally made up of vertical columns, the angled surfaces fitting into each other and giving rise to a zig-zag, like the sutures of a skull. Logan, in his report on the Geological Survey of Canada, suggests "that they have resulted from the crystallization of soda, which crystals were subsequently dissolved,

and the molds filled by the sediment that formed the succeeding layer." Worthen* thinks it probable that they were formed by the slipping or pressing together of the material under great pressure while in a plastic state. This is a plausible explanation where the floatings are parallel with each other, but specimens obtained from this limestone near Graydon Springs, in the northwestern part of the district, have the columns or fluting straight, and interlocking in all directions. It would be very difficult to explain how this structure could be formed by pressure, and some other theory must be proposed to account for this phenomenon. Examples, however, tending to sustain Worthen's views are presented in the fine specimens frequently found in the quarries in the vicinity of Springfield, where the structure assumes a columnar form, with a cup-shaped summit holding the lenticular masses of chert.

A regular variation is noticed in the limestone toward the south and east from Springfield, it becoming, like the chert, harder, more compact and finer-grained. The following characteristics may be given for this formation:

1st. The heavy-bedded chert, or thin, alternating beds of shaly lime and chert already described, which vary from a few feet to about 40 feet in thickness.

2nd. The limestone underneath, rather coarse-grained, crystalline, soft and greyish in color, usually having white, rather soft lenticular masses of chert, from a few inches to a foot or two in diameter, though the chert is occasionally absent. Rarely, some of the beds are of a faint greenish color. The so-called suture-joint structure is also characteristic. These beds sometimes alternate with coarse, more fossiliferous and thinner layers of granular limestone. The heavy beds are the ones that form the best quarries in this horrizon, and the rock, in these, often approaches marble in character. Where these layers are laid bare by removal of soil, the surface is covered with crinoid stems and brachiopods. Frequently a thin stratum of oolitic limestone is found in the upper layers

*Geol. Sur. Illinois, vol. I, p. 116, 1866.

of these beds. In the quarry in Tp. 29 N., R. XXII W., Sec. 27, Ne. ¼ of Ne. qr., this is 18 inches in thickness. The middle beds range in thickness from 60 to 100 feet.

3rd. The lower beds are decidedly shaly in structure, though much harder than the upper ones, and, where exposed, form shelving ledges, giving a rguged and barren appearance to the country. Frequently long slopes are covered with these tumbled slabs, making a barren belt, left to the coarse grasses and the cacti. Good examples of this structure may be seen where the Bolivar and Fair Grove roads cross the south fork of Dry Sac, in the long slope north of the ford in Tp. 30 N., R. XXI W., Secs. 33 and 34. Here the gullies and slopes of the hills are covered with these thin, conchoidal fragments of shaly limestone. At Jones spring (Tp. 29 N., R. XXI W., Sec. 27), is a splendid exposure of the lower beds of the Upper Burlington limestone. At the sides of the spring, and surrounding it for several hundred feet, on the hillside, are irregular and weathered ledges outcropping, giving a rugged and picturesque appearance to the place. It is an excellent locality for fossils, particularly the large coiled shell, *Euomphalus latus*, which seems to characterize the lower beds of the Upper Burlington in this area. These ledges, together with several old and abandoned quarries, form an excellent field for the collector. These upper and lower shaly beds are excellent guides to the geologist in locating himself in this formation. The aborigines took advantage of this structure in making their burial mounds, which may be found at various points along the Sac and James rivers, especially near Delawaretown, in the bluff on the west side of the James, just above the iron bridge. The chert in these lower beds, which have a thickness of from 50 to 80 feet, increases toward the southeast. This limestone is remarkably pure, containing only traces of silica, alumina, magnesia and iron. It is the freest from impurities of any limestone in the area.

The thickness of this formation at Springfield, as given by the well at the St. Louis and San Francisco car shops, is 215 feet, which is about the maximum. This great thickness and

the varying structure in the three beds just described, have an important bearing upon the topography of the greater part of the district. The broad plateau of the Springfield fold drops somewhat abruptly, by small bluffs and low hills, into the valleys of the streams, the middle beds usually forming the more or less vertical escarpments, covered with a cherty slope, caused by the decomposition of the shaly, cherty upper beds, and washing away of the lime. The erosion along the Sac and Wilson creeks, where they run through this formation, has been considerable, and is usually so abrupt as to render the valleys rarely wide enough for much cultivation. The slopes are covered with the chert debris, and, where the streams cut through into the lower beds, they are strewn with shaly fragments of the limestone, giving the ridges a rough and strikingly characteristic appearance. Along the James river, the bluffs are usually confined to one side of the stream, in which case the other side is an extremely rich bottom land running up into a gentle slope. But the broad, rolling plateau, where the residual chert is not too abundant, forms the main farming region of the area and of the whole southwest wherever the Upper Burlington limestone is found. This is especially true where denudation has affected the upper layers of the formation.

The decomposition of these alternating beds of limestone and chert forms a wonderfully rich soil. The breaking down of the very soft, porous, fossiliferous and ferruginous chert, with the red argillaceous material derived from the weathering of the limestone, forms a most favorable condition for vegetable growth. This mixture of red clay and broken chert gives the stranger, at first sight, a very unfavorable impression; but the fine crops raised in this area, and the wonderful strength of the soil, bear ample evidence to the fertility of the region.

The remarkable purity of the Upper Burlington limestone, its loose texture and coarse structure, render it readily acted upon by surface and percolating waters. The great strain brought to bear upon it by the formation of the folds in the development of the Ozark uplift, has fissured and shattered it to a much greater degree in some places than in others, and

this will explain the great variation in the farming lands in this limestone. Where there has been little or no shattering, and stream erosion has not affected it, the residual clay resulting from surface decomposition has formed an impervious layer that gives a cold, damp soil, except in times of drougth, when it becomes an ash-colored powder, forming the desolate post-oak flats—a condition well illustrated in the belt of country just south of the crest of the Graydon-Northview anticline, and in the greater part of Washington township (Tp. 28 N., R. XX W.) and a portion of Tp. 27 N., R. XXII W.—localities which have been before referred to.

From these facts we may draw some inferences as to how the geological structure of a country controls its development and growth.

Washington township (Tp. 20 N., R. XX W.) is one of the earliest settled townships in this area, dating its history back to 1836. Being almost wholly underlain with the Upper Burlington limestone, and surrounded by a well-settled farming region, numerous bright and rapidly-growing towns, and with excellent railroad facilities, it is, notwithstanding all these things, remarkable for being one of the most thinly-settled townships in the area, and for not having a single town or village within its limits. The reason for this state of affairs may be explained from geological conditions. Having no good surface or underground drainage, residual matter has formed the clayey, damp sub-soil just described. It is a broad, nearly level, but little diversified plateau, and what was once a prairie is now overgrown and largely covered by scrub-oak and post-oak flats. Where, however, such a plateau as this has been fissured or shattered by flexure, these cracks form natural water-ways for surface drainage, and, because of the easily decomposable nature of this limestone, soon establish underground cavernous water-ways, thus causing a thick and rich sub-soil, which is being constantly added to, making such splendid upland farming country as is found east and west in Campbell township, East Center, Wilson and Lincoln, and portions of other townships. The size of these underground water-

ways, and the immense amount of erosion produced by them, is shown by the number of splendid contact springs that mark the boundary between this formation and the Lower Burlington, the latter being an extremely hard and compact limestone which forms an impervious under stratum. The great springs are all Upper-Lower Burlington contact springs, and they will be more fully described in another chapter.

The numerous large and remarkable caverns, and the large number of sink-holes, which seem to have a greater or less regularity in trend, are further evidence of this erosion by underground streams. Even some of the surface waters sink and appear again, as, for example, Wilson Creek, which frequently disappears for short distances. These sinks are more common near the crests of the folds, and usually occur in groups. Professor Shaler, in the geological survey of Kentucky, believes the numerous caverns and sinks in that state are an evidence that the formations there have not been submerged since their elevation. If they had been, the caverns would have been filled by later deposits. We may reasonably infer that the Upper Burlington limestone has been dry land in this area since the time of the Ozark uplift. Near Osceola, Mo., some caves contain secondary deposits of sandstone which would indicate a second submergence in that region.

We are thus enabled to form some conception of the time involved in the formation of these subterranean water-ways, and their antiquity is further proved by the finding of Quaternary remains in caverns in this area.

The last geological condition to be mentioned which affects the farming lands of the area is found where stream erosion has been great. Here abrupt cherty slopes and bluffs give a rugged aspect to the country, and what is lost to practical interests is made up to the æsthetic sense in the great beauty of the scenery.

Natural bridges are occasionally found in this formation, as, for example, on the Storey farm, about four miles east of Springfield. Here, by walling up a part of the bridge over a spring, the owner of the land has made a very fine milk-house,

from which an underground passage leads to his dwelling. This spring was, probably, a contact spring between the Upper and Lower Burlington, as the contact was noted just below in the shallow ravine made by the falling in of the strata of a former cave.

Another natural bridge is found on the Mauzy farm (Tp. 28 N., R. XXI W., Sec. 3, Ne. ¼ of Ne. qr.). This beautiful bridge abruptly heads a narrow gorge about 100 feet wide, which extends up from the bottom lands of the James river. The county road formerly passed over it. This bridge is 50 feet long, 15 feet wide and 12 feet high. The bottom of the gorge is Burlington limestone. A fine spring issues from the bluff in the northeast corner of the gorge, and is conveyed by a trough to the interior of the bridge, which is now walled in and used as a milk-house. A series of several interesting Upper and Lower Burlington faults can be seen on the north side of the gorge. This is a good locality for Upper Burlington fossils.

A peculiar local variation of the Upper Burlington limestone occurs on the Cave Spring-Ebenezer road, in Tp. 30 N., R. XXIII W., Sec. 10, also in Tp. 30 N., R. XXIII W., Sec. 12. At these points an intercalated layer of a peculiar yellowish, fine-grained, sparkling sandstone is found, a few inches in thickness. At the two latter points it seems to be situated not far above the Upper and Lower Burlington contact.

The most troublesome variation, perhaps, to the geologist is the occurrence, at a number of points in the southeastern third of the area, of a bed of varying thickness, of a rock strikingly resembling the Chouteau in color and lithological characters. It was first noted and then mistaken for Chouteau on the James river, a quarter of a mile east of where Wilderness road crosses the river, in Tp. 29 N., R. XXIII W., Sec. 25. Here, and at several points along the James, a ledge of this Chouteau-like layer, a few feet in thickness, outcrops. It is, apparently, located in the lower part of the Upper Burlington, not very far above the Lower Burlington contact, and was mistaken by Swallow for Chouteau in his geological reportof the

country along the Southwestern branch of the Pacific railroad, 1859. (See his geological map of Greene county in this report, on which he locates Chouteau as outcropping at this point southward along the James into Stone county.) A similar Chouteau-like layer is frequently found underneath the chert beds in the upper part of the Lower Burlington, and has been referred to in the discussion of that formation. The bluffs along the lower James present some unusually fine points for the study of the different beds of the Upper Burlington. Just east of the bridge on the Springfield and Ozark road, in Tp. 28 N., R. XXI W., Sec. 16, Se. qr., in the vicinity of the Boiling spring, is a good location for studying the Upper and Lower Burlington contact and the lower layers of the Upper Burlington. From this point to the Owen farm, Tp. 28 N., R. XXII W., Sec. 29, there are splendid exposures of the upper, middle and lower layers in the precipitous bluffs which alternately occur on either side of the stream. One of the best exposures of the heavy-bedded middle layer is on this same farm, where is found a bluff 96 feet high, rising abruptly from the river, which is quite deep at its foot. This bluff is made up of a series of heavy beds from four to twelve feet thick, each having a convex surface, the bedding planes showing the effect of erosion, and giving the entire bluish-grey face of the bluff a wrinkled or scolloped appearance. On the summit are numerous Indian graves, made by piling up the thin, shaly layers of the upper beds. At the Wilson Creek battle ground (Tp. 28 N., R. XX W., Sec. 23), the opposing armies fought on a ridge covered with the debris of the upper shaly layer of the Upper Burlington. A rude monument of these stones marks the spot where General Lyon fell. In Tp. 28 N., R. XXIII W., Sec. 26, Sw. cor. Sw. ¼ of Nw. qr., to the east of the road, and on the north side of Robinson branch, a sharp Upper and Lower Burlington junction can be seen. A thin irregular layer of chert marks the unconformity of these formations. But few points have been found where the contact between the Upper and Lower Burlington can be carefully studied, owing

to the wreckage of the lower shaly layer, which covers up, in a slope, the line of separation.

In the northwestern part of the area this formation seems to have been deposited directly upon the Chouteau, the Lower Burlington being usually absent. The Morrisville-Brighton fold is made up largely of this formation, although it nowhere reaches a very great thickness. Lithologically, it presents characteristics similar to those already described, though it is, perhaps, less heavy-bedded, the shaly character predominating, and it is, as a rule, less cherty than the beds to the south.

So far, no authentic vegetable remains have been found in the Upper Burlington. Animal life, however, was abundant. A few obscure specimens of sponges have been found; radiates are somewhat common; a few corals, such as *Chætetes*, *Syringopora* and *Zaphrentis*, are present; and crinoids are abundant, particularly in the upper beds, where the stems are found in great profusion, and not infrequently the calyces of both blastids and crinids. The fragments are frequently water-worn and rounded, as though washed by off-shore currents. All the species here are much coarser in structure than those found in the Lower Burlington beds below. White* calls attention to the fact that the structure of the crinoids forms a means of distinguishing the beds of the Lower and Upper Burlington and the Keokuk. He notes that, taken as a whole, those of the Lower Burlington limestone are of smaller size than those of the upper. He further notes a variation in the delicacy of construction and surface ornamentation, together with a pleasing symmetry of outline of those of the Lower Burlington compared to the larger and coarser forms of the representatives in the Keokuk, where they reach a culmination of rudeness in their ornamentation, and a strange extravagance of form. Of the vermes, polyzoans are abundant, particularly in the upper chert beds, and brachiopods are very plentiful, the characteristic forms being the *Streptorhynchus crenistriatus*, *Spirifer logani*, *Sp. grimesi* and *Productus punctatus*. Of the mollusks, lamellibranchs are occasionally found, several species

*Geology Iowa, vol. I, p. 214, 1870.

of *Aviculopecten* having been taken from the upper limestone beds. Of the gasteropods, there are several species of *Straparollus*, which are characteristic, in the area, of the lower limestone beds. Of the arthropods, a small *Phillipsia* has been found. Of the vertebrates, a number of fishes teeth and spines have been found in the upper beds—all selachians, the teeth probably belonging to the genus *Deltodus*.

The following fossils have all been found in Greene county, those marked with * being given on the authority of Mr. Stuart Weller:

Spirifer grimesi, Hall.
Spirifer logani, Hall.
Spirifer striata, Martin.
Spirifer suborbiculares, Hall.
Spirifer keokuk, Hall.
Spirifer forbesi, Norwood.
Spirifer subcuspidatus, Hall.
Spirifer lineatoides, Swallow.
Spirifer cuneatus.
Spirifer lateralis, Hall.
Spirifer subequalis, Hall.
Spirifer increbescens, Hall.
Spirifer neglectus, Hall.
Spirifer pseudolineatus, Hall.
Spirifer lineata, Martin.
**Spirifer tenuicostata*, Hall.
Streptorhynchus crenistriatum, Phillips.
Streptorhynchus crassum, Meek & Hayden.
Streptorhynchus robusta.
Terebratula bovidens, Morton.
Terebratula formosa, Hall.
Terebratula burlingtonensis, White.
**Terebratula succulus*, Martin.
Orthis swallovi, Hall.
Orthis burlingtonensis, Hall.
Orthis dubia, Hall.
Productus punctatus, Martin.
Productus semireticulatus, Martin.
Productus equiradiatus, Shumard.
**Productus marginicinctus*, Prout.
**Productus cora*, D'Orbigny.
Productus burlingtonensis, Hall.
Productus wortheni, Hall.
Productus setigerus, Hall.
Rhynchonella mutata, Hall.
**Derbyia keokuk*, Hall.
**Eumetria verneuilana*, Hall.
Athyris lamellosa, L'Eveille.

Athyris royssii.
**Athyris planosulcata*, Phillips.
**Athyris trinucleа*, Hall.
Athyris incrassata, Hall.
**Strophomena analoga*, Phillips.
**Camarophoria subtrigonia*, Meek & Worthen.
**Syringothyris plenus*, Hall.
Discina sp.
Platyceras quincyense, McChesney.
Platyceras equilaterale, Hall.
**Platyceras fisturellum*, Hall.
**Platyceras acutirostre*, Hall.
**Metoptoma umbella*, Meek & Worthen.
Euomphalus latus, Hall.
Pleurotomaria montezuma, Worthen.
Myalina keokuk, Worthen.
Aviculopecten magna, Swallow.
**Conocardium indianense.*
**Conocardium meekanum*, Hall.
Hadrophyllum glans, White.
Zaphrentis varsoviensis, Worthen.
**Zaphrentis centralis*, Worthen.
**Chetetes illinoiensis*, Worthen.
**Amplexus fragilis*, White & St. John.
Archimedes sp. nov.
Syringopora harveyi, White.
Prismopora triftlia, Rominger.
Conularia sp.
Evactinopora quinqueradiata, Ulrich.
**Palæcis obtusa*, Meek & Worthen.
Phillipsia bufo, Meek & Worthen.
**Actinocrinus multiradiatus*, Shumard.
**Actinocrinus sp.*
Agaricocrinus wortheni, Hall.
Agaricocrinus bullatus, Hall.
**Agaricocrinus planoconvexus*, Hall.
Actinocrinus verrucosus, Hall.
Batocrinus nashvillæ, Troost.
Batocrinus shepardi, Rowley.
Batocrinus equibrachiatus, McChesney.
**Batocrinus biturbinatus*, Hall.
Batocrinus pyriformis, Shumard.
Batocrinus trochiscus, Meek & Worthen.
Batocrinus subtractus, White.
**Cyathocrinus iowensis*, O. & W.
Dichocrinus striatus, O. & S.
Dorycrinus parvus, Shumard.
**Dorycrinus cornigerous*, Hall.
Dorycrinus intermedius, Meek & Worthen.
Eucladocrinus pleurovimnus, White.
**Eretmocrinus virginarius*, Wachs.
Granatocrinus granulosus, Meek & Worthen.
Physetocrinus ventricosus, Hall.

**Platycrinus safordi*, Troost.
Platycrinus sp.
Steganocrinus pentagonus, Hall.
**Synbathocrinus swallovi*, Hall.
Tricoclocrinus wortheni.
Pentremites conoideus, Hall.
Pentremites elongatus, Shumard.

The formation is noted in the Southwest as the richest of the lead and zinc horizons. In the south, the rocks being much harder, the deposits are not so rich nor as extensive as in the Joplin and Aurora districts, this hardness being less favorable to the deposition and segregation of ore. The Upper Burlington limestone forms a good building stone and is largely sought after for that purpose in numerous quarries in and about the city of Springfield. The stone from many of the beds is susceptible of a fine polish, the upper fossiliferous layers resembling marble. The rock is very beautiful and durable and may be seen in the Drury College chapel, the St. John Episcopal church and other buildings in Springfield. As a road material the surface chert is widely used in Springfield for macadamizing. It can be seen on Boonville street and the National Boulevard. This is not, however, so good nor so durable as the chert from the lower formations. Its soft texture causes it to break down quickly and pulverize. A very important industry is the manufacture of lime from this rock. In the vicinity of Springfield and at Ash Grove a flourishing business has been built up and large quantities of lime are shipped.

DES MOINES SERIES (Coal Measures).

Of the coal-bearing deposits there are only a few outliers, composed of shale, sandstone and conglomerate represented. Three small coal pockets have been found within the limits of the area. One of these is not of workable thickness, and the extent of the others has not yet been ascertained. It has been impossible to thoroughly synchronize these deposits.

The coal measures are arranged in about this order: first, a rather coarse-grained, reddish sandstone, possibly the ferruginous sandstone of Swallow; second, in places overlying, and occasionally apparently merging into the ferruginous sandstone,

patches of micaceous sandstone and bowlder conglomerate, the conglomerate usually lying in elongated depressions in the micaceous sandstone—the Graydon sandstone, named from Graydon Springs, in Polk county, where it was first studied; third, in several localities, small patches of alternating beds of highly inclined shales, from blue to greenish-black in color, occasionally mixed with thin seams of carbonaceous matter, and frequently containing tumbled bowlders of fossiliferous limestone; fourth, and last, a peculiar knotted chert, named the Republic chert, from its great abundance around Republic. This covers most of the highest points and overlies, apparently, the highest formation of the district.

Of the shales, only a few pockets occur, and these are mainly confined to the extreme western portion of the area. The best section exposed is 4 miles west of Willard at the Kelso clay shafts (Tp. 30 N., R. XXIII W., Sec. 20, Ne. ¼ of Sw. qr.). The several shafts are from 20 to 30 feet in depth. The coal measures seem to lie in depressions in a micaceous sandstone and bowlder conglomerate. The lowest shaft on the slope of the ridge struck the micaceous sandstone at a depth of 16 feet. The bowlder-conglomerate lies around the shafts at the surface, especially on the west side. The center shaft, 30 feet deep, passed through the following strata:

		Feet.
5.	Soil and clay	2
4.	Limestone, fossiliferous, brownish bowlders	5
3.	Shale, variegated, reddish and greenish	3
2.	Shale, bluish, with thin seams of coal, containing fragments of plant remains	18
1.	Shale, bluish-black, with crystals of selenite	2

In No. 5, mixed in the soil from the surface to the depth of two or three feet, are found small rounded masses of a very peculiar clay which is wholly destitute of plasticity. These masses vary from the size of a nutmeg to several inches in diameter and in color from pure white through yellow, salmon, brown to light tints of blue and green. The masses are very compact, wholly free from grit and cut like tallow clay, which the salmon colored variety closely resembles in everything except plasticity. With the exception of one or two other locali-

ties in this township this peculiar variety of clay has not been noticed. It is, undoubtedly, a variety of halloysite. In No. 4 are found large bowlder-like masses of pinkish-buff and purplish drab, highly fossiliferous limestone, the fossils broken and their fragments frequently converted into calcite. The clay is light colored with a greenish tinge and is frequently filled with fragments of fossils. Numbers 3 and 4 are quite uniform in thickness, as is indicated in a number of shafts. Mixed through the latter are numerous bowlders or concretions of very dark, bluish, coarse-grained limerock, containining a few finely preserved fossils, apparently belonging to No. 85 of the general section of the Upper Coal Measures by Broadhead, and among them finely preserved archimedes, brachiopods and bryozoan corals. Frequently there are extremely thin, irregular layers of carbonaceous matter. The clay closely resembles the Billings deposit. Good pottery has been made from it. The two feet of black shale at the bottom of the section has green masses of soft shaly substance, together with some carbonaceous material and selenite crystals. Bowlders of the dark blue limestone extend into this layer, and are coated with clay which is filled with small crystals of selenite and pyrite.

Three and one-half miles south of Republic, at a locality called Wise Hill, in a depression on the northern slope of an elevation which is mainly composed of Upper Burlington, several shafts have been sunk in a deposit similar to the one at the Kelso place. The deepest shafts are respectively 45 and 34 feet. A careful inspection of the latter gave the following section:

		Feet.
8.	Soil	1
7.	Shale, red and greenish, mottled	3
6.	Shale, dark bluish-green, with selenite	8
5.	Shale, black with fragments of fossil leaves	10
4.	Limerock, dark blue, with streaks of selenite	⅔
3.	Shale, black, bituminous	5
2.	Limerock, dark blue, with pyrite and thin sheets of columnar calcite, one or two inches thick, coated with small crystals of selenite	1½
1.	Shale, bluish (exposed)	5

Large masses of clay filled with crystals of calcite, their planes running in every direction, were first struck at a depth of four feet and seemed to be confined to the beds above No. 4. The beds in this shaft dip to the east 6 inches in 5 feet. The deepest shaft, about 50 feet from the one just mentioned, and at the same level, struck no limerock until the bottom was reached at a depth of 45 feet. The rock found at the base of this shaft was a very hard, dark limestone containing both iron any copper pyrites. These shales are in a depression in the Graydon sandstone, which is itself deposited in a depression in the Upper Burlington, and all of these are covered by fragmental remains of the knotted Republic chert.

On the Cotter farm, 3 miles southwest of Willard (Tp. 30 N., R. XXIII W., Sec. 33, Nw. ¼ of Se. qr.) two shafts have been sunk in quest of lead and zinc in a deposit similar to that just described. These shafts are situated on the east side of a narrow valley that opens from Clear creek. The Upper Burlington outcrops on high points to the east of it, while a heavy deposit of the Graydon sandstone forms the crest of the ridge. On the surface of the slope, for some distance above the shafts to the east, Republic chert is scattered in large masses. The ten feet of a slope above the shaft is covered with micaceous sandstone. The shaft is 37 feet deep and from it the following section was obtained:

		Feet.
4.	Limerock, yellowish, fine-grained, containing oval masses of pyrite.	10
3.	Shale, yellow	10
2.	Shale, black, containing numerous gasteropod shells changed into pyrite.	10
1.	Limestone, bluish drab, and white chert, containing pyrite and small particles of zinc blende (exposed).	7

On the Long farm two miles to the west (Tp. 30 N., R. XXIII W., Sec. 31, Nw. ¼ of Ne. qr.), six shafts have been sunk in a depression in this sandstone. The strata dip to the northwest. The following section is shown:

		Feet.
4.	Soil	2
3.	Fine white clay	15
2.	Yellow ochre	85
1.	Conglomerate, gravel, white clay and sandstone, containing some lead	18

Northwest of Springfield is another clay bed (Tp. 29 N., R. XXI W., Sec. 5) intercalated in a thin deposit of Graydon sandstone which lies along the continuation of the McCracken fault. It is impossible to synchronize the different depqsits of clay, shale and limestone. The fossils are fragmental and dificult to definitely determine. Fossil plant remains are also found in the shale. In digging a cellar on the McAdam farm, near the north line of Tp. 4, R. XXIX W., Sec. 21, 5 feet of this clay and yellow ochre were passed through. The Graydon sandstone conglomerate is, perhaps, the most difficult in the whole area to determine. This formation is made up of two strikingly dissimilar deposits and both may be present or either may be absent, or they may be intercalated with each other in such a manner as to make it impossible to say which of them rests above or which below. It is extremely doubtful if the deposits of shale just described should be separated from the sandstone, as they are apparently imbedded in the conglomerate, as seen on the farm of Mr. Kelso. The sandstone is usually a rather coarse-grained, more or less friable, micaceous rock. It varies greatly in color and texture. Usually it is a dark or purplish red rock, frequently variegated in the same bed, presenting a very beautiful appearance. Occasionally it is milky to grayish white in color, as seen in a little draw just north of the Graydon Springs hotel, where one bed of it contains much fragmental carbonaceous matter and fragments of fossil leaves. Just south of the hotel, along the same branch, are a number of large imperfect *calamities*. The stream flows over different layers of shale and sandstone.

The weathering of the sandstone in places is very striking. It occasionally forms great ridges covered with rough and tumbled blocks and with ledges forming beetling bluffs that give a strange and wierd aspect to the scenery, as is seen in the Saway bluff in the southwest corner of Cass township (Tp. 30 N., R. XXIII W., Sec. 30, Nw. ¼ of Ne. qr.). At this point there is a narrow ridge capped with 70 feet of Graydon sandstone. A small branch that runs east into Clear creek has cut through it, exposing the ledges and tumbled blocks of the bluff

This is a fine example of erosion, and the rock exhibits the characteristic false-bedding so common in this sandstone, and its variegated color is very beautiful. The juncture with the Upper Burlington limestone at this place is sharp and shows marked unconformity.

About one mile south of the mouth of Asher creek is another similar and even more remarkable ridge of the same kind of sandstone. A small branch has cut through it nearly at right angles into the First sandstone which forms the bed of the stream. The tumbled blocks along the crest of the ridge, and the false-bedding and variegated colors, all make it a most interesting point. In Tp. 29 N., R. XXIII W., Sec. 17, a sand-pit was opened in the sandstone, and the material at one time hauled to Springfield. The bank has been dug out to a depth of about 15 feet. On the south side, false-bedding is noted. In the freshly exposed surface is a layer filled with small nodular masses from the size of a pea to one and one-half inches in diameter. These, when broken, are found to be filled with less indurated matter enclosed by a thin shell of limonite, the latter surrounded by sandstone. The disintegration of these nodules explains the cause of the pits and shallow depressions that characterize some of the beds of the Graydon sandstone. Below this layer are from six to twelve inches of fine white clayey shale. The conglomerate is found at various points in this vicinity.

A ridge that is still more interesting is found at the Warren bluff northeast of Strafford (Tp. 30 N., R. XX W., Sec. 25). The conditions presented are similar to the former cases cited. The headwaters of the Pomme de Terre cut through a narrow ridge of sandstone about 100 feet high, and 500 feet to the west a small branch cuts through it again leaving an isolated peak between the two streams. The Springfield and Marshfield road passes along the foot of the bluff in the latter draw. The river flows over a bed of Hannibal shale. The sandstone is made up of loosely aggregated, rounded, irregular, transparent to translucent quartz grains cemented with a whitish material. Frequently there are concretionary layers alternat-

ing with impure seams of iron, the different layers varying from yellowish, brownish, red and purple to white in color. It is often micaceous, though not uniformly so. The east side of the bluff which faces the stream is more precipitous than the other side and exhibits well the irregular bedding of the formation, the thin bedding planes becoming in places contorted and frequently pitted on the rough surface. Sometimes the beds are so much distorted that a longitudinal section of the face of the bluff resembles, somewhat, a vertical section of a series of funnels set into one another, or a structure such as one can imagine to have been deposited in powerful eddies. From the middle of the bluff upwards, small, rounded, waterworn quartz pebbles are occasionally noted. Within twenty or thirty feet of the summit, resting in a slight hollow or depression, as though it were the bed of an old stream, occurs the second variation of this formation, the conglomerate. This is made up of rounded, polished, waterworn pebbles varying from the size of a hickory nut up to several inches in diameter, cemented more or less firmly in a sandstone matrix. This seems to cap the sandstone for several miles in a ridge having a northwesterly trend. The southeast end of this ridge is very abrupt, and great irregular masses form ledges which stand out prominently. Commencing northeast of Strafford (Tp. 29 N., R. XIX W., Sec. 15, Nw. qr.), an area covering forty or fifty acres is the first appearance of the conglomerate on the eastern side of the district. The next outcropping is a short distance to the northward, in Tp. 29 N., R. XIX W., Sec. 31, and covers a fraction of an acre. It next appears in a massive ridge on the south side of Bucksnort hollow (Tp. 29 N., R. XIX W., Sec. 5, N. line of lot 7), and extends about a mile and a half in a westerly course, being about one quarter of a mile wide. The stone is deep purplish red in color and the surface somewhat pitted. The sand is mixed with small white quartz grains from the size of a wheat grain up to a pea. Denuded, rounded pebbles are found scattered over the territory between this ridge and the Warren bluff. From the latter point it con-

tinues in the ridge already described, having a width varying from a few hundred feet to nearly half a mile. Then for several miles only occasional indications of its former presence are found. However, it again assumes massive proportions, stretching for a mile or two to the northwest and where the Springfield and Buffalo road crosses it (Tp. 31 N., R. XXI W., Sec. 35), it averages one mile in width and is of great thickness. The pebbles here are very large. At this point, which is known as Edmiston hill, there seem to be indications of a junction of two branches, one from the east and one from the southeast. It is difficult to determine whether the ridge here is continuous with the deposit east of Pleasant Hope, or with the small outcrop south of Presley hill.

Passing back to the western townships of Webster county once more, a small ridge of conglomerate and sandstone is found in Tp. 30 N., R. XIX W., Sec. 23. The first example of a series of mounds that have been preserved by the capping of the conglomerate is the Bodenheimer mound (Tp. 30 N., R. XIX W., Sec. 9, Sw. qr.), which is nearly half a mile long by one-eighth of a mile wide, and rises nearly 150 feet above the river, with an abrupt slope beyond the Pomme de Terre. It is covered with rounded pebbles of the conglomerate, some of them having a diameter of six to eight inches. The deposit has an estimated thickness of 70 feet. This ridge is continuous in patches through section 9 to the middle of Section 7, Tp. 30, R. XIX.

The next outcrop is the well-known Fair Grove mound, one of the most beautiful in the district. It stands as a landmark for all the adjacent country. This mound is nearly two-thirds of a mile long and a quarter of a mile wide. It is about 150 feet high, and is capped by 80 feet of the conglomerate. The northwestern slope is much more gentle and it runs out into a low narrow ridge. The south branch of Pomme de Terre cuts through this ridge into the Second magnesian limestone, but the conglomerate is exposed on the west bank of Pomme de Terre capping a ridge that is evidently an extension of this one.

Other mounds dot the prairie to the west and north. The Newton mound (Tp. 31 N., R. XXI W., Sec. 2), is one of the largest in the area, on which the Hannibal is capped by 25 feet of the conglomerate. This is also a landmark for the surrounding country, and the view from its summit extends over a wide range. The abrupt slope of its south side to the Pomme de Terre is one of the best points in this area for the study of stratigraphical geology. To the west, and only a little over a mile away, is Goodnight mound, also capped by the conglomerate. Its slopes are so covered with debris that no accurate section is obtainable; the conglomerate is at least 40 feet in thickness. South of the last two mounds mentioned is Reed knob, Tp. 31 N., R. XXI W., Sec. 12, capped by the same conglomerate. Between the Goodnight mound and Pleasant Hope another outcropping of conglomerate is found. Just southeast and south of Pleasant Hope are still other small outcroppings of the conglomerate, and the debris, consisting of rounded pebbles and accasional blocks of sandstone, mark the old line of deposit at scattered points along the ridge from Pleasant Hope toward Morrisville.

Beginning in the southwestern part of the area, the conglomarate appears in patches stretching across Tp. 27 N., R. XXIII W., Sec. 35, and Tp. 27 N., R. XXIII W., Sec. 26, Sw. qr. The county road cuts through the next outcrop on the west line of Tp. 27 N., R. XXIII W., Sec. 21, Sw. qr. This is an outlier of the most remarkable outcropping of this deposit in the area--one that stretches from Tp. 27 N., R. XXIII W., Sec. 20, Se. qr., where it is half a mile wide, through the greater part of Tp. 27 N., R. XXIII W., Sec. 19, where it rapidly increases in width, stretching from the southwest corner of 19 to the middle of Tp. 27 N., R. XXIII W., Sec. 18, Sw. qr., where it reaches a width of a mile and a quarter. The county road runs north and south on the township line its whole width, and in many places resembles a natural cobble-stone pavement. This is, perhaps, the best point in the southwest to study this conglomerate. The bowlders reach a considerable size—from 4 to 8 inches in diameter, some of them being fossiliferous. At

one point on the county road (Tp. 27 N., R. XXIV W., Sec. 13, Se. ¼ of Se. qr.), quite a number of fossils were collected, having been derived, probably, from the Upper Burlington. The bowlders lie in obscure, ridge-like lines across the road, following, in general, the trend of the ridge. In Tp. 27 N., R. XXIII W., Sec. 18, Sw. qr., they have a strong northwest course. In Tp. 27 N., R. XXIII W., Sec. 19, Nw. qr., they bear more and more to a westerly course, while in Tp. 27 N., R. XXIII W., Sec. 19, W. ½ of Sw. qr., they begin to bear to the north and northwest. On the northern slope of this ridge, the pebbles decrease in size until they are no larger than rice grains, evidently derived from quartzite. In the northwest corner of Tp. 27 N., R. XXIII W., Sec. 20, a well was sunk 27 feet deep in this conglomerate. The pebbles decreased in size from the top to the bottom of the well, and the material thrown out beautifully illustrated the structure. When first excavated, the sandstone matrix was of a purplish red color, and so soft as to allow the pebbles to fall out, leaving their casts in perfect shape, while the matrix became decidedly harder on exposure to the air. This great deposit may be traced more or less continuously through to the railroad cut east of Billings, the point in the southwest where this remarkable deposit was first noticed, and from where it has been traced, in isolated patches, for nearly thirty miles to the northwest. Patches are also found in Tp. 29 N., R. XXIII W., Sec. 28, extending through to Tp. 29 N., R. XXIII W., Sec. 8; along the strip stretching from the southeast section of 32, northward through section 29 in Tp. 20 N., R. XVII W.; in Tp. 30 N., R XXIII W., Sec. 8, and further northward to Graydon Springs.

It has been already inferred from the description that the conglomerate, lying as it does on the margin of the great Western Interior coal field, corresponds in structure and in position to the Mill-stone grit of the earlier geologists. This was pretty thoroughly identified by Owen, in 1858, in his description of the great spread of somewhat similar material in the northern counties of Arkansas.

It seems probable, however, that this formation belongs to the Upper rather than to the Lower Coal Measures, to which the Mill-stone grit has been assigned. As this conglomerate lies below and intermingled with the Graydon Springs sandstones and shales in various locations, though chiefly below, there is little doubt that they belong to the same period. The fossils from these shales and the sandstones undoubtedly belong to the Upper Coal Measures.

It is very interesting to notice that Henry King,* M. D., who made, probably, the first geological exploration of the territory immediately north of this area, along the Osage river, seems in his report, to locate this sandstone above the Coal Measures, thus, at that early date, more accurately defining its position than some of the later geologists. Speaking of the sandstone, he says: "It is important on account of the iron ore connected with it. *It seems to overlie the coal and shale,* though it is possible that further investigation may prove it to embrace similar deposits. It is of various shades of yellow and red, and often passes into good and extensive beds of iron ore. * * * * * This sandstone constitutes many of the hills of the vast prairies lying on both sides of Grand river, in Henry and St. Clair counties. * * * * It is this sandstone that gives the sandy character to the soil of this region. This sandstone contains many vegetable impressions."

Of the various theories proposed to account for this remarkable formation, that of the estuary deposit will be first considered. Similar deposits usually outcrop in all countries in narrow strips on the borders of the Coal Measures. Such formations one might expect to find on a coast where the powerful river currents have brought down debris to be rolled, polished, sorted and finally mixed with a sandy matrix made of rounded and angular polished quartz grains, which differ from the pebbles only in size. In the quieter locations the waters would deposit the finer materials, forming the beds of

* Report of a Geological Reconnoisance of that part of the state of Missouri adjacent to the Osage river, in 1839, and published in the Journal of the Senate of Missouri, first of the Eleventh, 1840, pp. 517 and 418.

shale and clay, and these would contain the fragmentary fossil remains such as are found in the shales and clays of the area.

Another theory supposes that these deposits were laid down by the large rivers that drained the early continental areas. One would certainly expect to find many evidences of these ancient streams, which were, without doubt, powerful eroding agents at that period in the earth's history, when the rainfall must have been several hundred inches a year.

There are many arguments in favor of the view that the Graydon sandstone and conglomerate in this district are the remains of prehistoric river systems, and they seem especially applicable to the conditions found in townships 27, 30, 31 and 32, in range 23. In many places the evidence is strong that the sandstone and conglomerate have been deposited in a valley gouged out of the Upper Burlington, as is seen on the farm of Mr. Jesse Cotter, in Tp. 30, R. XXIII, Sec. 33. For several miles north and south of this place at various points, the sandstone evidently rests on the side-hill or slopes of the Upper Burlington, the latter formation outcropping on high points on either side of the sandstone deposit. The same is true at Graydon Springs. A quarter of a mile south of the hotel at this place, in a little branch, the contact between the limestone and sandstone is sharply marked, and from this point for a number of miles northward, Major E. W. Newton, states that the old valley is much more easily traced, and that there is every evidence, from well sections, and from the contour of the valley, that this old river flowed for many miles to the north, and had its outlet into the Osage west of Osceola. A current that would transport such an amount of bowlder material must have been very rapid and powerful. Its early action must have been to erode a channel which is well represented in the deep narrow valley at Graydon and northward. The trend of narrow ridges in the conglomerate deposit, in Tp. 27, R. XXIII, already described, is what one would expect to find in the dropping of deposits in rapidly-flowing streams, the small ridges corresponding to the currents of the stream. The variation in the size of the pebbles on different sides of the deposit is what one would

expect to find where the current was retarded on the inner curve of a stream, where the finer material would be deposited. This is well illustrated in the locality last referred to, and was noticed in the description of that deposit. Again, the deposits of clay, so characteristic in the depressions in this conglomerate, the tumbled bowlder masses of Coal Measures limestone associated with these clays, the fragmentary character of the plant remains found in this clay and shale (the last characteristic being especially noticeable in the clay deposited in the conglomerate at Billings), and the irregular and tilted bedding of the clay and shale, are all what one might expect to find in bends of great rivers and where the entering waters of tributary streams, retarding the main currents, would cause a deposition of the sediment carried by the waters.* Still again, the basin-like deposit of the conglomerate upon the Graydon sandstone northeast of Strafford, and the peculiar eddy-like deposits of the sandstones seen in cross-sections in the face of the bluff at this point, and already described on a preceding page, would afford strong evidence of the truth of this view.

At one point, on the summit of Edmiston hill, in Tp. 37, R. XXI, Sec. 35, there seems to be a junction of two branches, one from the east and the other from the southeast, and at such points the conglomerate seems to be heavier, and some of the patches of coarse conglomerate alternating with the sandstone ridges, seem to be due to the retarding influence of two meeting currents.

Where surface erosion has been great, this Graydon sandstone and conglomerate have withstood this force, and in some places is found standing out in bold narrow ridges, as seen in

* Ranke, in Page's Geology, p. 28, has shown, by experiment, that a current moving at the rate of three inches per second, will erode, and carry along fine clay; at the rate of six inches per second, it will carry along fine sand; at eight inches per second, coarse sand; at twelve inches, gravel; twenty-four inches, pebbles; three feet, angular stones the size of a hen's egg. It will be noted that the transporting power increases at a greater ratio than the velocity, and Le Conte has shown, in his "Elements of Geology," p. 19, that the transporting power of a current varies as the sixth power of the velocity, and, further, that the slightest retardation of the current tends to the immediate deposit of large portions of sediment. These facts will give some light on the rapidity of the current of the river which carried such large debris as described above.

Tp. 31, R. XXIII, Secs. 8 and 9, at Warren's bluff, northeast of Strafford, and many other points. Where the erosive action has been very great, this formation frequently protects great areas beneath it, making high mounds which stand up boldly above the level of the surrounding country. These mounds forcibly illustrate the amount of erosion which has taken place since carboniferous times, and good examples of them are found in the region south, west and northwest of Fair Grove.

Further, as to the nature of the deposits in the conglomerate, it should be stated that most of the pebbles in the deposits in the extreme eastern portion of the district seem to have been derived from the chert of the Lower Silurian formations which, further to the east, are exposed over large sections of country. At other points, in the western portion of the area, the chert has a Lower and Upper Burlington cast, while a great deal of it is of extremely doubtful origin. The presence of the small grains of pure, limpid quartz, as seen on the north line of the deposit in R. XXIII, Tp. 27, in Christian county, as well as at other points, and that forming the cementing matrix so generally diffused, together with the presence of mica, would indicate that they had their source in some granitic outcrop; but the distance of such an outcrop is too great to readily explain the agency of water in transporting it to the present location. The foreign nature of the pebbles in the mill-stone grit of Ohio has been the source of much speculation, and of a third theory, which Dr. J. S. Newberry* very ably discusses in his dissertation on the origin of mill-stone grit in Ohio. It will be remembered the belief has already been expressed that this conglomerate belongs to the Upper Coal Measures, and not the mill-stone grit, the conglomerates of the two, however, being somewhat similar in structure. Dr. Newberry believes that neither estuary nor river deposit will account for the formation of the mill-stone grit. He says: "The approximate uniformity in the thickness of the deposit and its similarity of composition over all parts of the area that it occupies, forbid the acceptance of river-action as the

*Geol. Ohio, vol. II, pp. 103-107.

agency of its distribution. Again, the action of narrow currents of water having sufficient velocity to transport such a mass of coarse material several hundred miles, would not be shown simply in such transportation, but these currents would deeply excavate the underlying beds over which they flowed, and which were at this time scarcely in any degree consolidated. Those waves acting upon this portion of the continent could not have effected such distribution, as they have no power to create quartz pebbles except as they have quartz rock to work upon. Advancing shore waves could, therefore, not have deposited two or three hundred feet of sand and gravel several hundred miles out upon a flat, composed altogether of fine material.

"In looking through the geological series for some similar deposit which could serve as an explanation of this one, I have found none that seemed to offer so close a parallel as the later drift deposits spread over the northern half of the Mississippi valley. Here we have in many localities a mass of material which, if consolidated, would form an almost perfect copy of the carboniferous conglomerates—beds of gravel in which the pebbles are, for the most, part, quartz, undistinguishable from those of the conglomerate, and sheets of sand, nearly or quite free from pebbles. It is true that most of the drift contains bowlders of larger size than any found in the conglomerate, but over large areas these are restricted to the summit of the series, and mark a distinct epoch in the chain of events. Throughout a wide area, too, we find the gravels and sands of the drift resting upon the lower, fine drift clays, precisely as the conglomerate rests upon the mud stones of the Waverly and the sub-carboniferous limestones. To explain the phenomenon presented by the drift deposits, I have been compelled to invoke the aid of floating masses of ice, and have suggested that the gravels and sand which form the upper layers of the drift have been floated to their present resting-places, frequently from points of origin 500 miles distant, and quietly dropped down upon the soft clays below; arguing that the currents of water, or currents of ice, transporting these grav-

els, sands and bowlders, could not have deposited them where they are found without tearing up the underlying clays."

The above somewhat lengthy quotation from Dr. Newberry is here given, in order that the variovs methods of accounting for a similar extraordinary deposit may be more readily compared, and to assist future workers in this region to carry on their investigations. It seems strongly probable that the most of these deposits in this area either fill ancient river channels or are portions of river deposits, and the reasons therefor may be summed up as follows:

First, the decided evidence of buried channels from the southwest corner of Tp. 30, R. XXIII, to Graydon Springs, as indicated by the sandstone deposit on the accompanying map.

Second, the lack of any uniformity or regular bedding in the deposits, which are laid down in more or less incoherent masses, although false bedding is not uncommon.

Third, the pocket-like deposits of tilted clays and shales, mixed with tumbled, bowlder-like masses of foreign limestone.

Fourth, the tumbled and fragmental deposits of fossil leaves and plants in the sandstone.

Fifth, the variation in the deposits in bends of the channel, the finer debris being dropped on the inner curve of the bend.

Sixth, the arrangement of the exposed bowlders and sand, in places, in trends apparently corresponding to the eddies and irregular currents of the stream.

Seventh, in cross sections obtained in bluffs, as referred to the Warren bluff, northeast of Strafford, where the irregularity in the debris resembles what one would expect to be deposited by small eddies and whirlpools.

Eighth, a cross-section of the last-named bluff indicates the position of the conglomerate upon the sandstone as filling a second basin.

Against this view may be briefly mentioned the following:

First, the enormous size of these supposed rivers, reaching at Billings, a width of nearly two miles.

Second, the great number of these supposed streams within a small area, there being three within four miles of each other northeast of Strafford, each having a width varying from a quarter to a half mile.

Third, the great fall that they must have had, the enormous rapidity of the current, and the great body of water necessary to have carried debris having bowlders of such great size.

Fourth, the source or origin of the quartz in the pebbles and coarser sand, the chert pebbles being more easily accounted for.

In answer to some of these objections, it may be said, in general, that the rainfall must have been enormous, reaching several hundreds of inches a year during and following the carboniferous period. (See Le Conte's "Elements of Geology," p. 372, for discussion of this subject.) Consequently the size of the streams must have been immense compared to those of to-day, and the erosion correspondingly great.

In the early part of this chapter it has been said that possibly these deposits occasionally lie upon and merge into the ferruginous sandstone. The word "possibly" was used because of grave doubts of the existence, in this area, of that formation known to Swallow as the ferruginous sandstone.

A list of localities where small patches of this sandstone are found is here given:

Near center of S. line of 23, 32, 23, in the road just northwest of the hotel at Morrisville.

In the Se. of Nw. ¼ of 26, 32, 23.

In the Nw. ¼ of 27, 32, 23.

In the Ne. ¼ of 33, 32, 21.

Near the middle of the S. ½ of 3, 31, 23.

In the E. ½ of Sw. of 26, and the N. ½ of Nw. of 35, 31, 23, at church and cemetery.

Near the middle of W. ½ of Se. of 34, 31, 23, on the Hammontree farm.

In the middle of Se. of 35, 31, 23.

In the Ne. of Nw. of 2, 30, 23.

Near the center of W ½ of Ne. of 4, 30, 23.

Just north of Cave Spring, in the Se. of 4, 30, 23.

In the Nw. of Ne. of 10, 30, 23.

In the E. ½ of 21, and the W. ½ of 22, 30, 23.

In the N. ½ of 32, 30, 22.

North of the middle of the N. ½ of 20, 30, 21.

In the Ne. of Nw. of 20, 30, 21.

East of the middle of S. line of 19, 30, 21 (?).
Near the Johnson Mines, just Sw. of middle of 29, 30, 20.
The middle of the Nw. of 12, 30, 20, the Sampson Bass farm.
Near the middle of 3, 29, 21, near Reilley & Heffernan's park.
On the Brower farm, near middle of N ½ of 5, 29, 23.
Near the middle of W. ½ of 4, 29, 23.
Se. corner of 10, 29, 23.
In the Sw. of Se. of 14, 29, 23.
In the S. ½ of Se. of 16, 29, 23.
Near the middle of the S. ½ of 35, 29, 23.
South of the middle of the W. line of 32, 29, 23.
On the N. line of 5, 28, 23.
Near the middle of Nw. of 4, 28, 23.
In the Ne. of Ne. of 2, 29, 23.
The S. ½ of N. ½ of 10, and the N. ½ of S. ½ of 10, 28, 23, and the Se. of 9, 28, 23.
The N. ½ of 15, and the Ne. of 16, 28, 23.
Several patches in the Se. of 17, 28, 23.
The Ne. of Ne. of 20, 28, 23.
Patches running diagonally Nw. through 21, 28, 23.
The center of S. ½ of Sw. of 22, 28, 23.
The Se. corner of 14, and the Nw. corner and center of 24, 28, 23.
The Se. of Se. of 30, 28, 23.
The center of the Se. of 18, 28, 22.
Near the center of the S. ½ of 19, and the center of N. ½ of 30, 28, 22.
Several patches in the Nw., center and Se. of 30, 28, 22.
The center of the W. ½, and the center of the S. line of 11, 27, 22.
The center of Se. of 10, 27, 22.
The Ne. of 6, 27, 24.
Near the center of 8, 27, 23.
The Ne. of 17, 27, 23.
Center of the Sw. of 22, 27, 23.
Several small patches in the W. ½ of 29, and the N. ½ of 32, 27, 23.
Tp. 31, R. XXIV, Sec. 3, Se. ¼.
Tp. 31, R. XXIV, Sec. 3, Sw. ¼.
Tp. 31, R. XXIV, Sec. 6, E. ½.
Tp. 31, R. XXIV, Sec. 8, Se. ¼.
Tp. 31, R. XXIV, Sec. 13, Nw. ¼.
Tp. 31, R. XXIV, Sec 16, Nw. ¼.
Tp. 31, R. XXIV, Sec. 21, Se. ¼.
Tp. 31, R. XXIV, Sec. 22, greater part of W. ½.
Tp. 31, R. XXIV, Sec. 24, Nw. ¼.
Tp. 31, R. XXIV, Sec. 34, Ne. ¼.
Tp. 31, R. XXIV, Sec 36, E. ½.
Tp 32, R. XXIV, Sec 26, Sw. ¼.
Tp. 32, R. XXIV, Sec. 29, W. ½.
Tp. 32, R. XXIV, Ses. 30, W. ½.
Tp. 32, R. XXIV, Sec. 33, Ne. ¼.
Tp. 30, R. XXIV, Secs 4 and 5.
Tp. 30, R. XXIV, Sec. 9, Ne. ¼.
Tp. 30, R. XXIV, Sec. 11.
Tp. 30, R. XXIV, Sec. 13, Se. ¼.
Tp. 30, R. XXIV, Sec. 14, N. ½.

Tp. 30, R. XXIV, to south line.
Tp. 30, R. XXIV, Sec. 27, Se. ¼.
Tp. 30, R. XXIV, Secs. 32 and 33.
Tp. 30, R. XXIV, Sec. 35, Nw. ¼.
Tp. 29, R. XXIV, Sec. 1, Ne.
Tp. 29, R. XXIV, Sec. 4, W. ½.
Tp. 29, R. XXIV, Sec. 5, E. ½.
Tp 29, R. XXIV, Sec. 6, Ne. ¼ and W. ½.
Tp. 29, R. XXIV, Sec. 7, W. ½.
Tp. 29, R. XXIV, Sec. 8, N. ½.
Tp. 29, R. XXIV, Sec. 30, center and Se.
Tp. 28, R. XXIV, Secs. 5, 6, 7 and Nw. of 8.
Tp. 28, R. XXIV, Secs, 28, 29 and 30
Greater part of the N. ½ of Tp. 27, R. XXIV.

THE REPUBLIC CHERT.

This peculiar and striking chert has nowhere been found bedded within the limits of the district. It seems to be widely spread, in small blocks and masses, as a kind of residual material left by the breaking down and destruction of superincumbent beds over a large portion of the higher points within the district, and overlies, apparently, all the other formations. The chert is so striking that it cannot fail to attract the attention of even the most casual observer. It stands midway between the Upper and Lower Burlington cherts in texture, and it presents itself under two types, the first a distinctly stratified form, in which the bedding planes are represented more by coloration than by any difference in the texture of the layers. The alternating light and dark bands of the chert are due to the presence of iron in greater or less degree, this element being distributed in such a way as to give a banded appearance to the rock. It is highly fossiliferous, being filled with minute cavities representing broken crinoid stems, with occasional fragments of brachiopods too small to be determined. The alternating bands of brown and bluish-white are, undoubtedly, brought out by the burning over of the surface by forest fires. A large mass freshly broken presents, internally, a more evenly colored surface, although the bedding planes are distinctly noticed as consisting of porous layers alternating with those that are more dense.

The second form of this chert is still more extraordinary. It is a dense, compact conglomerate of small, oval, agatized masses of chert, solidly merging into each other, and made up of alternating layers of brown and yellowish or bluish-white bands, the texture of these bands corresponding to that in the other variety described. Frequently the darker bands merge into a form of clay ironstone. They are often highly fossiliferous, containing fragments of Streptorhynchus, probably *S. crenistria*. From its coloration, this variety, at a little distance, is frequently mistaken for blocks of sandstone. Occasionally, as on the farm of Mr. Kelso (Tp. 30 N., R. XXIII W., Sec. 20), the chert masses assume a concretionary structure, and, occasionally, contain geodes of quartz crystals. East and south of Buckley, this chert is scattered over the fields in masses from six to ten inches in diameter, and has the typical agglutinated, agatized, sand character.

This chert is widely distributed, especially in the extreme western part of the area, and in ranges XXII and XXIII, south of the Polk county line. It is particularly abundant in the center and eastern parts of Tp. 29 N., R. XXIII W., where it has frequently been piled up into stone walls; also east of Ebenezer, on the post-oak flats, it is quite abundant, and on the prairies between Brookline and Republic. In and around the coal measures deposits on the Kelso farm, Tp. 30 N., R. XXIII W., Sec. 20, it is widely distributed over the beds of shale and conglomerate.

TERTIARY.

Deposits closely resembling the gravels that collect on river beds to-day, but lying so high above, and frequently so distant from the streams that their origin can hardly be referred to, recent stream deposits are met with in places within the area. Several such gravel beds have been discovered in Greene county, notably the one found just west of Gates station on the Chadwick branch of the St. Louis and San Francisco railroad, Tp. 28, R. XXI, Sec. 20, Sw. qr. This is situated at an altitude of 40-100 feet above the James river, and from a quarter

to about a half a mile west of that stream. The deposit has been exposed for about a quarter of a mile along the right of way of the railroad, and the county road running southwest from Gates indicates its extension for something less than a mile in that direction. This has been before referred to under the head of Road Material. Another small outcrop has been noticed not far from the Rockbridge road, east of the iron bridge which crosses the James. It is believed that these gravels belong to the problematical Lafayette formation of the Pliocene. They rest unconformably upon the Burlington, and are unconformably overlaid by the Pleistocene. No fossils are found, and while many authorities regard the Lafayette sands and gravels as of marine origin, referring them to the Pliocene, others believe them to be Pleistocene, and to have been formed from the melting of the first ice sheet.

PLEISTOCENE.

No evidence of Pleistocene, or glacial drift has been found, as the area lies too far to the south. The Pleistocene is well represented, however, by the usual residuary deposits of soils, clays and cherts, the beds varying in thickness from a few inches to 30 or 40 feet, being much thicker and more widely distributed over the Upper Burlington limestone than over the other formations. The variations, as represented by the different horizons, and their important relations to agriculture have been discussed in connection with each formation described.

Frequent reports have been made in regard to bones found in the caves of the region. Only one case has been investigated, and this was on the Owen farm northwest of Springfield (Tp. 30 N., R. XXII W., Sec. 35, Ne. qr). In this cave were found a large number of bones of pleistocene age. In 1885, in excavating just south of the roundhouse of the Kansas City, Fort Scott and Memphis railroad shops, in Springfield, a well preserved mastodon's tusk 8 feet long was found in a horizontal crevice in the limestone. It was imbedded in black mud.

GEOLOGICAL STRUCTURE.

The area comprised in the Greene county sheet lies in a broad belt across the Ozark Uplift, not far from its center. The central axis of the Uplift, or the Springfield fold, forms a diagonal extending approximately through the middle of the area, at an angle of about 15 degrees north of east. Professor G. C. Broadhead, in his valuable paper published in The American Geologist for January, 1889, was the first to describe and name the Uplift.

In the following description of the flexures and folds of this Uplift, great care has been taken to distinguish between the true dip and the local dip produced by the undermining of the so easily decomposed strata of many of the horizons of this region. It has been difficult to accurately define the course of the axes, or to trace some of them out over the whole extent of the sheet. The Uplift, as exposed in this district forms a somewhat complicated system, made up of four divergent anticlinal folds, which are:

1. The Springfield anticline.
2. The Graydon-Northview anticline.
3. The Bolivar-Marshfield anticline.
4. The Chesapeake-Kirbyville anticline.

The synclinal valleys noted are as follows:

1. The South Sac-Ash Grove syncline.
2. The North Sac syncline.

To the northwest, beyond the area, the Uplift extends in billowy anticlinal folds, gradually diminishing as they approach the Missouri river.

THE SPRINGFIELD ANTICLINE.

This is the central axis of the district. Entering Greene county in about its southwest corner, it passes in northeasterly course, essentially outlined by the St. Louis and San Francisco railroad, until it reaches Springfield; then, turning to about 15 degrees north of east, it passes through Strafford, and leaves

the area just north of Northview. The northern slope of this central axis, especially that part between Springfield and Northview, is much more abrupt than the southern slope. Commercial street, in the city of Springfield, is the crest of this part of the fold. Water from the north gutter of the street flows into the Sac, Osage and Missouri, to the north, and that from the south gutter into Wilson creek, James, White and Mississippi rivers.

The "Frisco" railroad, eastward, approximately follows this crest which becomes sharper and more elevated as it leaves the district near Northview. The north slope, in places, breaks into some very interesting faults, especially along Dry Sac valley, near McCracken's mill, in Tp. 29, R. XXI W., Secs. 3 and 4, and these probably continue westward, as faulting has been located at Ritter's mill, Tp. 29, R. XXII, center of the east side of Sec. 4. Block faulting is also noticed on the southern slope, in Bucksnort Hollow, between Tps. 29 and 30, R. XIX. To the east this fold is well developed through Marshfield, Lebanon, and still further on in the same general direction.

West of Springfield, the fold broadens out into a wide belt of prairie, upland of upper Burlington limestone. The Carthage and Mt. Vernon roads lie just to the north of the crest to the Lawrence county line.

The southeast corner of the area is more or less elevated, forming the north slope of what will probably be found to be another fold, outside of this district, slightly diverging from parellelism with the Springfield fold.

An examination of the map accompanying this report will give a general idea of the flanks of these two great folds.

THE GRAYDON-NORTHVIEW ANTICLINE.*

In the north half of the sheet a great asymmetrical anticlinal fold, having a general southeasterly course—20 degrees south of east—enters the area in the southwest corner of Polk county, in Tp. 31, R. XXIV, Sec. 6, and merges, apparently, into the Springfield fold just west of Northview. This has been named the Graydon-Northview anticline.

From the abrupt slope of the Springfield fold, which merges into the synclinal valley through which the Dry Sac flows, a more or less gentle elevation to the north leads to a broad plateau which merges into the crest of Graydon-Northview anticline. The northern slope of this fold is, in places, very abrupt, breaking at a number of points, into a series of block faults, forming the asymmetrical variety of an anticlinal fold. In other places, the strata are greatly tilted, and a synclinal valley is formed, through the west half of which the North Dry Sac flows throughout nearly its whole course in this district, and to which has been given the name of the North Dry Sac syncline, since to the southeast the valley narrows and becomes more obscure, as the fold gradually merges into the Springfield fold.

Unusually good points for outlining sections and studying the block faults along the anticline are on the Cave Spring and Morrisville road, in Tp. 31, R. XXIII, Secs. 4 and 9; in the region a mile and a half south of the Sac and east of this point, in Tp. 31, R. XXII, Secs. 17, 18, 20 and 29, on the Springfield and Morrisville road, in Bird Eye hollow; on the Springfield and Bolivar road on Presley hill, Tp. 31, R. XXII, Secs. 16 and 22; on the Springfield and Pleasant Hope road, Tp. 31, R. XXII, Secs. 13 and 24; at Edmiston hill, on the Springfield and Buffalo road, in Tp. 31, R. XXI, Secs. 24, 25 and 26; and

*This disturbance, which was described as a monocline in the earlier pages of this report has been more extensively studied during the long interval that has elapsed between the printing of the first and later pages, and the more recent research points to the fact the uplift is more probably in the nature of an asymmetrical anticline.

two miles south of Fair Grove, along the Ebenezer and Marshfield road.

An interesting example of the probable effect of these flexures upon the early drainage system of this country is exhibited about a quarter of a mile east of Northview. At this point the "Frisco" railroad runs on a trestle over a small valley that crosses the main water-shed at right angles. There is evidence that the James river used to flow through this valley and formed a continuation of the Pomme de Terre river on the north. It now, however, flows to the southwest, having been turned from its original channel by the elevation of the Uplift. A glance at a geological map of the state will show this change.

THE BOLIVAR-MARSHFIELD ANTICLINE.

This great fold occupies all the area north of the Dry Sac syncline. The crest probably enters the district in Tp. 32, R. XX, Sec. 16, passing southeastward near Elkland, and leaving it near Tp. 32, R. XIX, Sec. 35. This great anticline will be more thoroughly described by Major E. W. Newton in his report on the Bolivar sheet. It seems to be somewhat crumpled, and made up of, at least, three obscure folds or wrinkles simulating small anticlines. In passing from the North Sac syncline across this great fold, the first minor flexure seems to to have its axis on a line between Morrisville, Brighton and Fair Grove. Its southern slope is decided, while on the north there are obscure indications of a shallow synclinal trough. The second minor fold seems to have its axis on a line drawn just north of Pleasant Hope, southeastward to the crossing of the Fair Grove and Elkland road at the Pomme de Terre, where the Second and Third Magnesian limestones are elevated. In passing through Dallas county, on the Buffalo road, one is constantly impressed with the strong dip of the rocks to the south, and the great elevation of the First sandstone until the main crest of this fold is reached in Tp. 32, R. XX, Sec. 16. Northward from here, to Greasy creek, outside of the area, on the Buffalo road, the dip is strongly to the north. In the south

half of Sec. 17, and the north-half of Sec. 20, Tp. 32, R. XX, is found an isolated mound capped with Upper Burlington, and exposing Chouteau and Hannibal. The West Bend and Morrisville road well illustrates the slight flexure upon which Morrisville stands. The section on the Springfield road and Bolivar road, from the foot of Presley hill on the Sac, through Brighton, gives a strong dip from the latter town to the south, and a very slight one to the north. On the Springfield and Pleasant Hope road this slight fold is still outlined, and still further north the Pleasant Hope fold is developed. In the northeastern corner of Greene county, and in the portion of Webster county included in this sheet, the Brighton and Morrisville fold is well outlined near Fair Grove, and also at Bodenheimer mound in Webster county. The Pleasant Hope fold is obscurely indicated near Sand Spring.

THE CHESAPEAKE-KIRBYVILLE ANTICLINE.

This anticline and probably its accompanying faults, passes through the southwestern corner of our sheet, about midway between the towns of Billings and Marionville. It has been traced to the northwest in Lawrence county, and to the southeast in Stone and Taney counties. The high uplands covered with the Upper Burlington wreckage conceal the continuity of the fold in this territory. It was first discovered two miles southwest of Paris Springs, in Lawrence county, in passing up the branch that heads by Johnson's distillery near this point. Magnesian rock, probably the Second Magnesian limestone, was found in apparent juxtaposition to the Upper Burlington. At the top of the bluff, a hundred feet above this point, members of the Chouteau group outcrop. About a mile to the northwest, along the line of this disturbance, at the big spring in the southwest corner of Tp. 29, R. XXVI, Sec. 36, Second Magnesian limestone again outcrops, and may be followed southeast down the branch toward the Johnson distillery. In the bluff, and around the sink-hole just above the spring, outcrops of the Chouteau are found. A short distance to the northwest along the line of the disturbance, at the top of the

hill above the distillery, just north of the center of Sec. 1, Tp. 28, R. XXVI, at an altitude of about 200 feet above Turnback creek, Hannibal shales may be seen in juxtaposition with Second Magnesian limestone on the west side of the road. The amount of the disturbance may be estimated by the fact that Turnback creek flows through a valley of Upper Burlington limestone. Swallow, on the geological map accompanying his report on "The Southwest Branch of the Pacific Railroad," notes the presence of the Chouteau group at this point, but does not note the fact of its having been brought up by the faulting along this anticline. The extension of this disturbance and the accompanying faults southeast to Chesapeake is well exhibited. At the springs near the town of Chesapeake, Magnesian limestone, probably the Second, abuts against the Upper Burlington, the heavy upthrow being on the east side of the fold. Another interesting locality, and the most northwesterly point which may be studied along the line of this fold, was discovered by Major E. W. Newton, at Williams' spring, on the north line of Lawrence county, Tp. 29, R. XXVI, lot 5, Nw. qr. of Sec. 5. South of this area, evidence of this fold may be noted in northwestern Stone county, Tp. 26, R. XXIV, Sec. 13. Winslow, in his Lead and Zinc Report, p. 430, quotes Mr. Edwin Harrison describing a line of disturbance or faulting in Taney county, about six miles west of Forsythe, crossing White river in a Nw. to Se. direction. A line drawn from this point to the Williams spring before referred to, in Lawrence county, would probably mark the outline of this anticline. A general parallelism may be noticed between this and the Green Forest (Arkansas) and Verona anticline, which the writer has been studying in connection with Major E. W. Newton, who first discovered it. Although the localities here described are all outside of the particular area to which this report is devoted they are noted in order to indicate the extension of the anticline through this area, and it is hoped that these data may stimulate further research into the history of the Ozark Uplift.

South of the Springfield anticline, a series of axial or lateral anticlines have been outlined mainly from studies out-

side of the district, and a remarkable relation seems to exist between them and the location of the mining areas on the south, a relationship that certainly must be more than a coincidence.

This subject has been referred to under the head of Lead and Zinc, and if the relationship which seems so apparent can be verified by more extended study, especially to the south and east, it will throw great light upon the origin of the ore deposits of the southwest. The study and mapping of seventy or eighty of these mining areas, some promising and others worthless, have resulted in the finding of but one minor exception to what, it is believed, will develop into a general law. (See chapter on Lead and Zinc.) The large majority of these mining camps are outside of this district, and the connections of the folds of this extra-limital region, with their probable extensions into this area, cannot well be indicated on the accompanying map.

The geological history of southwestern Missouri is of great interest and of considerable complexity, and it cannot be completely elaborated until a more thorough study of the southern half of the state and of northern Arkansas has been made, especially in regard to the Archæan, Silurian and the Devonian formations. Several times in this report reference has been made to the quaquaversal at Decaturville on the lines between Dallas and Camden counties. Mention has also been made of the gradual elevation of the lower formations in passing from the southwestern part of the district to the northwestern corner on to Decaturville, where is found the only granite outcrop in this part of the state.

There is reason to believe that in Archæan times, this portion of Missouri consisted of an archipelago of islands, surrounded by a broad ocean. It is probable that the magnesian limestones and sandstones of the Silurian in the greater part of the district were formed as relatively shallow water deposits over the submerged portion of one or more of these primitive islands, the vicinity of Decaturville probably representing an elevated point on one of these islands. Later, the Decaturville area was subjected to a stronger elevation, or

protrusion, which produced the quaquaversal. Studies to the west indicate the continuation of the general dip westward. It is interesting to note that Henry King, in 1839, in his "Geological Reconnoisance of the Osage river" (The Journal of the Seventh of Missouri, the First of the Eleventh, 1840, p. 518), states, in speaking of this region of country, that "the general dip of the strata is, as before observed, between 2 or 3 degrees. The direction is in accordance with the general dip of the basin, that is, west of north, about the mouth of Sac river, north in Morgan county, and perhaps a little east of north in Cole county. The maximum dip is near the outcrop of the strata, whilst lower down in the basin, as in the northern parts of Benton and Morgan counties, it is scarcely perceptible. Besides this general dip, there are many local ones which, though limited, and produced by local causes, are sometimes so extensive as to produce some apparent confusion. This is remarkably the case on the Big Gravois and Niangua."

Dr. King's observations would aid in sustaining the view that the Decaturville outcrop is somewhere near the main crest of the uplift, and is, without much doubt, a portion of one of the early Archæan islands. The highly-tilted Silurian strata immediately around this granitic nucleus, being sometimes almost vertical, also show that an uplift has taken place since the Silurian rocks were laid down, and it will be seen, later on, that the rocks in this locality have probably not been submerged since this elevation at the close of the Silurian. The rocks subsequently laid down along this western slope of the Ozark islands were evidently off-shore deposits, there being a deep sea to the west and south which gradually and successively receded southward and westward, leaving the more fragmental deposits near the coast line, and the finer, deep sea deposits to the west, as has already been indicated under Stratigraphical Geology.

At the close of the Carboniferous, the Springfield anticline was still further elevated, and the anticlinal folds to the north were formed. That this took place after the Carboniferous,

seems to be indicated by the evidence obtained from ancient river beds, which are now elevated across the Uplift.

Respecting the history of the formations but little can be said, and that only in the most general way. From the composition of the Silurian deposits, it is inferred that the alternations of limestones ond sandstones show successive oscillations from deeper seas to shallow, off-shore deposits. The characterstics of the limestone beds, as noted in the chapter describing them, show an upper and lower layer of cherty, silicious, honeycombed (when weathered*), magnesian limestone, with massive beds of hard, compact, purer magnesian limestone between. This seems to be uniformly true of both the First and Second Magnesian throughout the district. The silicious honeycombed beds seem to be beds of passage to the sandstones above and below. This curious mixture might be accounted for on the supposition that they were deposited by rapid currents in relatively shallow water, while the sandstones which preceded or followed them were laid down in quieter shallow water. The heavy-bedded purer central limestone beds seem to represent periods of quiet deposition and deeper seas. From the hard, chalcedonic and agatized cherts of the Silurian limestones might be inferred the possibility of metamorphism from the silicious ooze, which was probably their original condition. From the unconformity between the Calciferous and the overlying beds, and the great interval that exists between these Silurian rocks and the Devonian, it will be inferred that great erosion must have taken place. The geological formations from, and including, the Second Magnesian down probably belong to the Cambrian system, while the First Magnesian limestone and the First Sandstone probably belong to the Calciferous stage of the Lower Silurian, or Ordovician system. An erosion interval, and the few fossils that have been obtained in this part of the state would point toward this conclusion, although these formations have generally, throughout the text, been referred to as Silurian.

* These are fine examples of differential weathering

These beds, when elevated, represent, on the geological map, that large area occupying the center and southern part of the state which has been named the "Ozark Island."

The Devonian beds, represented by the thin strata of limestones, sandstones and shales, outcrop along the old coast line of the Ozark island, and steadily increase in thickness toward the south. They indicate a period of considerable oscillation of the crust, and their frequent absence, their irregularity of deposition when present, and their great variation in thickness, together with their rounded, water-worn fossils and pebbles, and their impure composition indicate that they must have been laid down as off-shore deposits.

The Kinderhook beds somewhat resemble the Devonian, though they were, undoubtedly, deposited in quieter and probably brackish water, as the western ocean formed a deep embayment in the Ozark island over the portion of the State that now comprises Greene, Webster and Christian counties. The impurity of their composition and the small size of the species of their brachipods and other fossils would indicate that the waters were still turbid and restless. They were formed, without doubt, largely from eroded material from the Silurian formation. The magnesia contained in their composition would aid in confirming this view, and it also sharply distinguishes this group from the Upper and Lower Burlington above. The slight erosion interval between the Kinderhook group and the Lower Burlington, and the conformity of the former upon the Devonion, would help to sustain the view of the Denovian nature of this (Kinderhook) group. In the chapter on the Lower Burlington formation it has been shown, by the gradual increase in the percentage of chert from the Springfield anticline toward the southwest, that a broad open sea extended in that direction during the deposition of those beds. From the uniform deposit of chert in the upper part of the Lower Burlington, as well as the break in life that has been referred to in the chapter on the last-named formation, and the decided lithological differences between the two, one would consider these limestones as belonging to two distinct formations.

The Upper Burlington, from the purity of its composition and the number and size of its fossils, indicates a state of pure and quite waters during its deposition. After the elevation which brought the Upper Burlington epoch to a close, there was, evidently, a period of great denudation. There are strong reasons for believing that the mass of residual chert and debris scattered over a wide extent of the territory are the remains of denuded upper beds of this, and possibly other horizons succeeding the coal measures. The excessive rainfall necessarily connected with the ancient river beds, and the deep channels which those streams eroded and subsequently partially filled with conglomerate and sandstones, as illustrated at and north of Graydon Springs, are additional proofs for the confirmation of this view. A few small patches of coal measure deposits represent the outliers of the great coal beds on the west. The heavy residual accumulations of Republic chert overlying the highest points would indicate a partial incursion of the sea during the latter part of the Carboniferous, as they seem to overlie the coal measure pockets. Following this, the great uplift that brought the Carboniferous age to a close produced the folding and flexuring which have been described as the Ozark Uplift* Since this time, this area has been above the ocean, as is indicated by the lack of deposits in the Upper Burlington caves, unless the few deposits of the cementing gravel, notably that deposit found just west of Gates station on the Chadwick branch of the St. Louis and San Francisco railroad represent a local Tertiary deposit, in which case it is possible that there was a submergence of a portion of the old "Ozark (Silurian) Island." Near Osceola, however, outside of the area, a secondary deposit of sandstone is found in some of the caves, which would seem to indicate a slight incursion of the sea from the north or west since Upper Burlington times. From the very small isolated deposits of Upper Burlington limestone, resting in slight depressions upon the Second Magnesian just outside of the area, one in Tp. 32, R. XIX, Sec. 12,

*It is important to note that the trend of the Uplift shows some parallelism with the Ouachita Uplift of Arkansas.

Se. corner, on the east side of the Niangua river, and another on High Prairie, Tp. 32, R. XX, Sec. 1, Sw. ¼, and Sec. 12 N. ½, it is supposed that this portion of the Ozark island was above water up to Upper Burlington times. The small patches of Upper Burlington, Chouteau and Hannibal in Tp. 32, R. XX, Sec. 20, N. ½, and Sec. 17, S. ½, to the west of the two patches noted above, and resting upon First Sandstone, indicate the slope of this island to the west.

FAULTS.

A large number of faults have been noted in this area, but only a few the more important ones can be described in the limits allowed for this report.

First, at the Pierson creek mines, occurs a series of interesting dislocations. Near the center of Tp. 29, R. XXI, Sec. 35, W. ½ of Ne. ¼, just before the old road approaching Pierson creek crosses the stream to the point where the mines are located, the Chouteau, which outcrops along the bank ten feet above the stream, suddenly disappears, and Lower Burlington ledges are found in the same horizon. The slip here cannot be fully determined, because of the slope of chert which conceals the beds. The strike is probably more or less parallel with the course of an axial anticline, northwest and southeast, and the throw is estimated to be about fifteen feet. A short distance to the south, near an old lime kiln, is another obscure fault of about the same throw and strike. Two or three hundred feet to the south of this point, at the old shaft on the east side of the river, under the bluff, is an extremely interesting fault connected with the main fissure at Pierson creek. This fissure and fault, a few years ago, were beautifully exposed for study along the greater part of the face of the bluff, but it has since been filled in by the debris from other shafts. At that time the following notes were obtained: A vein fissure, 8 ft. in width, extending in a course N. 35° W., occurs here, having a dip of about 60° to the Ne. A fault is also finely exhibited, having a strike and dip corresponding to the fissure course, and a throw of twenty feet. The hanging wall is higher than the foot wall; the reverse of what is usually the case.

Near McCracken's mill, on the north slope of the Springfield anticline, about 1,000 ft. southwest of the colored schoolhouse, Tp. 29, R. XXI, Sec. 5, E. ½ of lot 4 Ne. ¼, a small quarry was opened a few years ago, exposing Louisiana limestone, at the same level as the lower beds of the Upper Burlington limestone, lying to the south. A shaft has recently been sunk at this place, and when visited, though full of water, the material in the dump showed that First Sandstone had been reached at a depth of 16 feet, after passing through Phelps sandstone and Sac limestone. Exact data could not be obtained. The line of disturbance could be traced about a quarter of a mile to the west side of the Sander spring branch, which now empties into the Water Valley mill pond, where tumbled ledges of Upper Burlington on the south abut against a slightly metamorphosed rock which considerably resembles Louisiana, although it may be modified Sac limestone. The continuation of this faulting is found in the Ramsey clay bank, in Tp. 29, R. XXI, Sec. 5, W. ½ of lot 4, Nw. ¼. Further to the west evidence of faulting is traced along the South Dry Sac to Ritter's mill, Tp. 29, R. XXII, Sec. 4, middle of east line. Here the Chouteau is in juxtaposition with the lower part of the Upper Burlington. Another good point for the study of this disturbance may be seen in the excavations made in the extension of North Grand street in the city of Springfield, where the road crosses the branch just north of the north line of the Reilly and Heffernan (Zoo) Park. Considerable disturbance is noted in the peculiar outcrop near the south line of Tp. 30, R. XXI, Sec. 19, on the Witherspoon land. The latter point needs more careful study. An outcropping here, closely resembling First Magnesian limestone in both weathering and lithological characters, is found associated with the Upper Burlington limestone and Graydon sandstone. No decided evidence of a fault could be found, and this outcropping may, after all, be only a peculiar local modification of the Upper Burlington.

By far the finest exhibition of faulting in the whole area, and, as far as known, in southwest Missouri, occurs along the northern slope of the Graydon-Northview anticline. This

slope, as before stated, varies greatly. Within short distances from each other are found greatly tilted slopes of the different formations, succeeded in a few miles by abrupt slopes broken into a series of block faults, with a throw of from two up to over two hundred feet, the line of fracture, in most cases occurring in the Hannibal sandstone and shales and the First Sandstone, these seeming to be the points of greatest weakness. The heaviest faulting seems to occur between Presley hill on the Bolivar road and the Cave Spring-Morrisville road, in Tp. 31, R. XXIII, Sec. 9, E. ½. The Bolivar branch of the St. Louis and San Francisco railroad, from Buckley to the Sac river, a distance of about five miles, passes over a very steep slope of this anticline, and although a part of it is outside of the area under discussion, the section is such a good one that it is here given. Buckley, situated on Upper Burlington limestone, has an altitude of about 1,200 feet, while the Sac lies at an altitude of 885 feet.

On the Cave-Spring Morrisville road several heavy faults occur in Tp. 31, R. XXIII, Sec. 9, E. ½. Here the First Sandstone abuts against the Hannibal sandstone. This fault extends for several miles through this region to the southeast. Passing down Bird Eye hollow, on the Springfield and Morrisville road, in the northwestern part of Tp. 31, R. XXII, the following section is obtained: Leaving the Upper Burlington limestone on the high crest of the anticline in Tp. 31, R. XXII, Sec. 28, Sw. ¼, at an altitude of 1,260 feet, a gentle slope of 25 feet of Upper Burlington is passed over, down to an altitude of 1,235 feet and then comes a short slope of 10 feet of Chouteau, down to 1,225 feet, where begins a long Hannibal slope of 45 feet, to the altitude 1,180 feet at the top of the Louisana limestone, and a long slope of this formation for three-quarters of a mile, with a fall of 65 feet to a small outcrop of First Sandstone, at the altitude of 1,115 feet. The sandstone is succeeded for a short distance, in the bed of the creek, by Second Magnesian, and this is followed by a long slope of nearly a mile of First Sandstone to an altitude of 1,030 feet, whence a Second Magnesian slope extending down to a point where it

seems to abut against a Lower Burlington slope at an altitude of 1,040 feet, in about the middle of Tp. 31, R. XXII, Sec. 18. Hannibal is found bedded at an altitude of 1,010 feet, in Tp. 31, R. XXII, Sec. 18, N. ½, just south of the ford on Little Sac, this stream flowing over Hannibal at an altitude of 980 feet.

The large section given across the area shows the remarkable series of block faults just described as occurring at Presley hill, on the Bolivar road, two and one-half miles east of Bird Eye hollow. The section very clearly shows the faulting at this point. In passing over the post-oak flat just before reaching Presley hill, at an altitude of 1,277 feet above the level of the sea, the first fault recognized is in Tp. 31, R. XXII, Sec. 34, near the north line. This break is indicated by a narrow draw to the east of the road, and also by a well section 28 feet deep on the Stokes farm, in the Ne. of the Nw. of the Nw. of the section last given. Chouteau was struck at the depth of 26 feet, showing a sudden break in the heavy deposits of Upper Burlington to the south. The next fault occurs at an altitude of 1,200 feet, in Tp. 31, R. XX, Sec. 22, center of Sw. ¼, where the Louisana abuts against the First Sandstone. A few feet to the north, at an altitude of 1,180 feet, the First Sandstone abuts against the Second Magnesian. A few hundred feet to the north from the last station, at an altitude of 1,165 feet, the Second Magnesian again abuts against the First Sandstone. Near the Middle of the western line of the Nw. of Tp. 31, R. XXII, Sec. 22, at an altitude of 1,100 feet, the First Sandstone abuts against the Hannibal. Going over a small hill of Upper Burlington limestone, at the same level as the First Sandstone to the south, i. e., 1,125 feet, a long slope of Hannibal and Sac limestone is passed over to First Magnesian limestone, through which last formation the Sac river flows, at an altitude of 1,007 feet.

Many other faults have been noted along this interesting anticline, especially in Tp. 32, R. XXIII, Sec. 17. Se. of center, in the road that crosses the Bolivar branch of the St. Louis and San Francisco railroad, a short distance along the side-hill north of the water tank, where two small faults are noted;

where the Springfield-Pleasant Hope and Springfield-Buffallo roads cross the anticline; and also on the Bannister farm in Tp. 30, R. XX, Sec. 30. Se. ¼ of Nw. ¼, where a heavy-bedded and tilted Lower Burlington ridge lies on the north side of the valley. On the south side, near the Bannister house, a shaft has been sunk in Chouteau and Hannibal at the same level as the upper beds of the Lower Burlington in the bluff on the side. Further south from the shaft at Bannister's, and on the ridge, 60 to 80 feet higher, is a broad belt of the Hannibal.

On the Hill farm, Tp. 29, R. XIX, Sec. 5, W. ½ of lot 7, Ne. ¼, on the north side of Bucksnort hollow, is a very remarkable series of block faults, on what is probably the southern slope of the Springfield anticline, and not far from where the Graydon-Northview anticline merges with it. The strike of the faults in this locality is about N. 40 degrees W. The Hill spring, in the valley at the south, is a Chouteau spring. On the north side of this valley, near the bottom, are beds of what is, probably, Second, or, possibly, First Magnesian. Twenty feet up the side of the valley outcroppings of First Sandstone are found, representing a thickness of about five feet. Above this, outcroppings of either First or Second Magnesian are found. Passing over ten feet of these beds, First Sandstone is again found bedded. Fifteen feet above the outcropping of the First Sandstone, Upper Burlington limestone is found bedded, with Chouteau in horizontal juxtaposition on the east. In ascending a gentle slope to a point thirty feet above the last station, tumbled blocks of Hannibal sandstone are passed over, and 20 feet beyond this is the summit of the ridge, which is covered with Lower Burlington chert. Following the southern descent of this ridge, more than 85 feet of tumbled chert is passed over, with no outcroppings visible until bedded Hannibal is reached, which, as has been stated, lies 85 feet from the summit.

Another interesting disturbance with faulting is found on the farm of John Caldwell, in the east part of Taylor township, Greene county, Tp. 29, R. XX, Sec. 24, N. ½. The farm-house stands on a gray, thin, coarsely crystalline, crinoidal Upper

Burlington limestone. South of the house, a block of Hannibal limestone seven or eight hundred feet wide is upthrown. The course of this fault is Nw. and Se. The Hannibal and Louisiana limestones are very thick at this point, and no Chouteau appears, while the Magnesian limestone (probably the Second) outcrops at a spring south of the house. This disturbance, which consists of several parallel faults, is best studied in the outcrops on the section above mentioned.

It has been impossible to present more than a meager outline of the most prominent physical features of this interesting region; but it is hoped that the facts here given may be of some use to the future student. Certain it is that the thorough study of this system of flexuring will throw great light on the history of the Ozark uplift.

ECONOMIC GEOLOGY.

LEAD AND ZINC DEPOSITS.

Although but little developed as yet, recent prospecting and examination indicate a much wider distribution of the lead and zinc ores than is generally supposed. This is especially so over the southern half of the area. In the sections adjoining the south, and on the east, there are numerous mines which have been, in the past, very productive. Such are the Alma, Turkey creek, Bull creek, Lang, Hornbeak, Pardom, Bray, Seneca and others in Christian county; while the old Hazelwood, the Seligman and numerous other mines ten or twelve miles to the east, in Webster county, were very productive in the early days when lead alone was sought. To the west, is the Ash Grove group, and the Pickerel creek mines, while the Aurora camp lies less than a dozen miles from the southwestern

NOTE.—The distances given in the above slopes refer to altitude and not horizontal measurements. It is impossible to accurately indicate these faults on the map, for the following reasons: First, they are rarely exposed, except by erosion in the gullies and roads; second, the summit of the Graydon-Northview anticline is a vast post-oak flat composed of residual clay and chert, which completely hides everything beneath, and as this ridge is a very sparsely settled region, few well-sections or foundations expose the rock beneath. Locations are accurately described in the text, so that they may be easily found by anyone wishing to make further investigations.

corner of the area. With a few exceptions, all of the productive mines within the limits of the area lie on the southern slope of the Springfield anticline, and south of the main line of the St. Louis and San Francisco railroad.

As in other parts of the southwestern portion of the state, the ores of lead and zinc are almost invariably found intimately associated. The ores of lead are represented by:

Galena, or lead sulphide ("blue mineral," "lead").

Cerussite, or lead carbonate ("dry bone," "carbonate").

Pyromorphite, or lead phosphate ("green lead").

Anglesite, or lead sulphate.

The ores of zinc are:

Sphalerite, or zinc sulphide ("jack," "rosin," "black jack," and blende").

Smithsonite, or zinc carbonate (zinc, "dry bone," "carbonate").

Calamine, or zinc silicate ("silicate").

Hydrozincite, or hydrous silicate.

Of the above, only galena, cerussite, sphalerite, calamine and smithonsite are found abundantly enough to be classed as workable ores. The remainder are usually of rather rare occurrence.

The associated mineral and gangue in the crevices and ore-bodies are as follows:

Calcite, or lime carbonate ("tiff").

Dolomite, or magnesian lime carbonate ("tiff," "spar").

Marcasite, or iron bisulphide ("white iron pyrites," "pyrites," "mundic").

Chert, impure flint.

Jasperite, a secondary deposit of silicious material, cementing the ores and gangue.

Greenockite, or cadmium sulphide.

Tallow clay.

Copper pyrite.

Limonite, hydrated sequioxide of iron, yellow orchre.

Ores are found in all the geological formations, from the Second Magnesian limestone through to the Upper Burlington, but they are not equally distributed. Only four productive horizons for lead and zinc are recognized, and these are: the Upper Burlington limestone, the Hannibal shales, the First Magnesian and the Second Magnesian limestones. The relative productiveness of these is about in the order named. All of the other horizons are, virtually, barren, and no profitable mines in any horizon in the southwest, outside of those mentioned above, are known except in the lower Magnesian limestone. The ores are found in three principal ways:

First, as "float" mineral. In this condition, rounded, water-worn weathered chunks and particles of ore, epecially galena, dry bone, blende and silicate, are found mixed with soil, clay, broken masses of chert and limestone, scattered somewhat irregularly in pockets within a few feet of the surface. This would be more properly called "drop mineral," as Owen suggested years ago. Its origin is evident, it having been derived from a broken-down crevice in superincumbent beds, or segregated some distance from the original deposit by the action of running water.

Second, segregated ore. In the upper portion of crevices where the beginning of a true ore body is found, the ores and gangue are more or less disturbed from their original position, and are mixed with residual clays (the "tallow clay," or selvage of the miner), the wall-rock having been broken down and partially washed away, while the contents of lateral crevices were washed in by subterranean drainage, and the heavier ore segregated with the main ore body.

Third, the crevice, or ore-body proper. In this the wall-rocks are generally well defined, particularly in the Magnesian limestone, though frequently broken into irregular, more or less horizontal "flat openings," where the ore and gangue have penetrated for some distance. Here the ore-body, which includes the ores and gangue, is rather massive and solid, filling up more or less completely the shattered crevice. These crevices are usually nearly vertical, penetrating to unknown depths,

and vary in width and thickness between the different formations, and even in the same formation.

It will be noticed, from the study of the distribution of the lead and zinc mines within this territory, that they bear such a relation to the flexures and foldings as indicates an intimate connection with them, viz., that the fissuring and filling of the crevices were brought about by the shattering of the horizons in the formation of the folds produced by an uplift. It will be observed, first, that all the mining camps lie on the flanks of the Springfield anticline of the Ozark uplift, rarely, if ever, within four or five miles of the crest, and that within the area which this report describes, they are confined to the southern slopes. No productive mine is found directly upon the crest of the uplift. Second, within this territory, and along some adjoining extra-limital areas, the productive mining camps are invariably found on the western slope of the axial, or lateral, anticlines; never on the eastern slope, and rarely in the synclinal valleys.

A careful study of the compass course of the ore-bearing crevice in each mining camp, and the relation of the different mining camps to each other, brings out the following facts:

1st, the compass course of the ore-bearing crevice is, in general, parallel to the axis of the axial folds, or anticlines.

2nd, the mining camps seem to be distributed in groups on the western slopes of these anticlines, indicating a continuity of the crevices over considerable distances along the western slopes of the same folds.

A careful study of the great ore bodies in the Upper Burlington limestone of southwest Missouri, and the extension of many of these into the Magnesian limestone ore bodies in the southern part of the State and in Arkansas leads to the conclusion that the ore and gangue which fills these fissures have come from below in solution in hot alkaline waters. They could not have come, as some have supposed, in a fused condition, as no heat is known sufficient to melt some of the gangue, as calcite, without disassociating the various constituents. Again, if the contents of the ore-body had been deposited

in a state of fusion, the wall-rock would have been more or less metamorphosed, which is not the case. Equally strong arguments may also be brought against the sublimation view as a means of accounting for the sources of these deposits, and there is little doubt that these ores and their gangue, all being easily soluble in hot alkaline waters, have come from below in a state of solution. In this condition they have been carried upward through the open crevice, where they have soaked and penetrated horizontally into the shattered walls and for some distance into the rock itself (where the latter is sufficiently porous), filling cracks, crevices and small cave-like openings, and being therein precipitated by various agencies. The more open and porous the formation, the larger and richer the ore bodies, while conversely, the harder and more compact the formation, the poorer and smaller the mineral deposit. Thus the great breadth of the ore-bodies and their remarkable richness in the Upper Burlington limestone is accounted for by the porous nature of the rock, and the readiness with which water decomposes and erodes cavities in it. The various heavy runs of mineral in this formation are contained in the shaly and more porous layers. In striking contrast to the rich deposits of the Upper Burlington is the barrenness, in this area, of the Lower Burlington, which immediately underlies it. In the latter formation are found all of the most unfavorable conditions for the accumulation of an ore-body. The hardness and compactness, both of the limestone and the chert, have made it impossible for the ore-bearing solutions to penetrate more than a very little beyond the limiting walls of the original crevice.

Below the Upper Burlington, the Hannibal shales are the first beds met with that present favorable conditions for the accumulation of ore. The folding of the rocks has caused a shattering of the shales into which the solutions have penetrated, forming a broad, rich, though rather thin, ore-body, which is recognized as the second ore horizon of the area. Below this, in the First Magnesian, where the beds are sufficiently soft and porous, is the third ore horizon. It is a note-

worthy fact that the sandstones are, without exception, almost wholly destitute of ore. They contain only the narrow crevice through which the superincumbent beds have been supplied. In the Second Magnesian is found the fourth ore horizon. In this the ore-body rarely exceeds eight feet in width, thickening and thinning locally, and frequently having flat openings due to shattering and subsequent erosion, where richer and broader deposits are found.

It has been said that the crevices are usually nearly vertical and continuous over considerable areas. They form parallel groups, but the parallelism must not be understood to be perfect. The planes are not always straight, either horizontally or vertically. The cracks in plaster caused by the sagging of a ceiling of a room well illustrate, though in an exaggerated manner, the actual condition of the crevice. The breaks in the ceiling forming a more or less waving line, retain, to a degree, their parallelism to the sag, running for some distance and then disappearing, to be followed by other cracks, starting a little to the side, but still in the same general direction as the first. On this same plan the groups of mining camps, with more or less unproductive territory between, can be accounted for. Erosion may also contribute to the unproductive region by exposing some of the barren horizons. This view also assists in explaining why some of the crevices seem to "pinch out" in sinking a shaft, or in drifting on a fissure. "Pinching out" is a term which miners apply to such a sudden closing in, both vertically and horizontally, of the walls of a rich ore-body, until the mineral almost entirely disappears. This phenomenon may be explained as follows: Faulting is not an unusual accompaniment of these crevices. If one will picture to himself their undulating walls, and suppose a slip of one wall to occur in such a manner as to bring the two concave surfaces together, there would be found a series of elliptical openings, rich in ore, tapering at each end to narrow passages which lead to successive and similar openings. This phenomenon may take place either in vertical or horizontal planes, according as the slip may be vertical or horizontal.

The order of the deposition of the ores and gangue near the surface is usually different from that deep down in the crevices. Near the surface are what may be called secondary ores or carbonates, "dry-bone," phosphates, and sulphates, though the last two are quite rare, and only of local occurrence. Deeper down the carbonates and sulphates are rarely, if ever, found. They are derived by chemical reaction from the primary ores, the metallic sulphides of lead and zinc. It is interesting to note that where a heavy outcrop of "dry-bone" is found in a broken down crevice near the surface, the probabilities are strong for a rich deposit of the sulphides below. The order of deposition of the ore, while not absolutely uniform, and varying considerably in different camps, is, generally, as follows: first, galena fills all the lower cracks and openings that were caused by fracture, or left by the solution of the lime; next, the zinc blende in a similar manner fills all other cracks and openings formed by subsequent erosion, or formed by a second slight displacement and opening of the fissure, and consequent shattering of the rocks. Coating the galena, in turn, are sometimes crystals of marcasite, or white iron pyrites. Then follows calcite, and after it dolomite, filling cavities, and still more recent openings wherever there is room for it. While this is the most usual order of deposition, there are many variations from it. It is quite probable that the zinc silicate was deposited in some cases after the zinc blende. Frequently there is a second deposit of zinc or galena, more frequently the latter. Many interesting specimens may be obtained from the mines, showing this sequence of deposition. Masses of blende may occasionally be found attached to the wall-rock coated with crystals of galena, upon which are found minute crystals of marcasite, and upon this last crystals of calcite and dolomite. The marcasite more usually forms drusy coatings, which gives a very sparkling appearance to the ores.

During the intervals between the opening of the crevice and the successive deposits of ore, the crevice serves as a natural water-way for surface and percolating waters. The action of such waters dissolves out and carries away the lime

of the neighboring wall-rocks of the crevice, segregating the broken flint and heavier mineral in the channel. This broken material may be, in turn, cemented by subsequent depositions of ore, thus forming the brecciated masses so common in the upper portions of the ore bodies. Occasionally, and fortunately rarely, a secondary deposit of silica held in solution cements the ore to the gangue in such a manner that a thorough separation by gravity (jigging) is next to impossible. Rarely there is found a crevice filled wholly with gangue, without a particle of ore, and, of course, utterly valueless. An isolated case occurs not far from Republic, where a shaft has been sunk to a depth of over 60 feet in a brecciated body which contains no ore.

It is now proper to consider what light the observations thus far made will throw upon prospecting for mineral, and the development of mineral land within the area. Some points will be considered which, in the beginning of this chapter, were referred to a later period in the discussion, and while what is here written applies particularly to the area covered by this report, the suggestions given are equally applicable to the adjoining territory.

Let it be supposed that a man wishes to know what are the probabilities of finding mineral on his farm. The first point to be ascertained will be the geological horizon in which the land is situated. If it be in the Lower Burlington, or any of the other formations classed as barren, it may be said with great certainty that, while ore may be found, it will not be in paying quantities, and it will be necessary for the prospector to calculate the depth to which he will have to go before striking one of the recognized ore horizons. If this land is situated in the Upper Burlington limestone, he may know that he is in the right formation for ore, and his next question will be as to the situation as regards the system of flexures of that region. If his land lies along the crest of the Springfield anticline, it can only be said, guardedly, that the probabilities are against finding any paying deposit. If it lies on one of the eastern slopes of an axial anticline, on the south of the crest, the

probabilities, so far as known, are still against his finding an ore-body. If it is on the western slope, the probabilities of finding ore are greater, and the proximity of the land to other mining camps, or its distance away from them, will throw some light upon the prospector's expectations. Let it be supposed that he is in the immediate vicinity of a paying deposit. How shall he proceed, as cheaply as possible, to demonstrate the presence or absence of ore-bodies. He will discover the course of the crevices in the adjoining mines, and note the situation of his own land in relation to such a mining camp. If it lies due north of the developed land, the compass course of whose crevice is N. 20 deg. W., he should sink a prospect shaft on an extension of the crevice line into his territory. It is an almost invariable rule, that the crevices are continuous through the bedded rock to the soil. Consequently, in sinking a prospect hole, all that is necessary to do is to sink until a crevice-opening or solid limestone is struck, in which latter case he should stop at once, instead of drilling, as so many prospectors fruitlessly do. If he is very anxious to thoroughly test his land, he can do so at a reasonable expense, in the following manner: Remembering that the crevice courses, in the supposed case, run N. 20 deg. W., and that the ore-bodies of the Upper Burlington are from thirty to sixty feet wide, he reduces the problem one-half by the knowledge that he must sink his prospect shafts at right angles to this line. Staking off his territory in a line east and west, prospects shafts may be sunk every sixty feet until solid limestone is struck. Or, if the soil is very shallow, a trench just wide enough for a man to dig may be sunk to solid limestone, in an east and west course across his tract, in search of the crevice. Care should be taken, either in the shallow shafts or in the trench, to notice whether the solid limestone that is struck is tilted and broken down, or not. If a shaft strikes a rock that tilts strongly to the west, and is evidently undermined, there is strong probability that the tilting is due to the sagging of the wall toward the crevice, and he should immediately drift in the direction indicated by the tilting, where he is likely soon to

strike the ore-body. Surface indications may aid him, to a degree, before he begins to prospect. This especially applies to the lower ore horizons. Dr. D. D. Owen in his report on Geological Explorations of part of Iowa, Wisconsin and Illinois, 1844, p. 40, calls attention to these "symptoms," as he calls it, of lead ore, and it is interesting to notice, in this old report, that he considers these deposits as formed in fissures. Featherstonhaugh, in his report upon "The Elevated Country between the Missouri and Red rivers," p. 50, also described these deposits as occurring in true fissures. See, also, Dr. Swallow's discussion of the question in his "Geological Report of the Southwest Branch of the Pacific Railroad," p. 88.

Owen says that whatever indicates the vicinity of a fissure may be considered as indicating the probable neighborhood of lead ore. As these crevices form natural water-ways for subterranean drainage, the surface is usually more or less undermined, so as to form a line of shallow sinks, narrow, shallow ravines, or more commonly slight depressions or "sags," these last being usually so slight as to be scarcely noticeable. On hillsides, the "sag" is represented by a bench. Whenever such a condition is noticed in a mining region, and the depression has the general compass course of the crevices in that vicinity, it is an excellent indication of the presence of mineral. Along such a "sag" the vegetation is usually more luxuriant and the trees larger, because of the moist and looser soil below.

The outlets of springs on hillsides are frequently the means of leading one to the crevice which forms the basis of the water supply. But the best indication of all is the finding of small particles of mineral or "tiff" in the soil.

ORIGIN OF ORE DEPOSITS.

There are several diverse theories in regard to the origin of the ores of lead and zinc, which somewhat correspond to the areas in which the subject has been successively studied. The earlier geologists, including Schoolcraft, Featherstonhaugh, Swallow, Owen, and Percival of Wisconsin, confined their attention to the deposits of the Lower Magnesian series, where

the veins were narrow and deep, and the walls more or less well-defined. They were almost unanimous in the view of the vertical ascension of the ore, i. e., through fissure veins. Later the discovery of the enormous deposits of ore in the Upper Burlington in southwest Missouri, in a rock that was so soft and porous that the subsequent erosion by percolating waters almost completely destroyed the limiting walls of the original fissure, together with the great thickness (from 200 to 400 feet) of the limestone, led geologists to confine their studies almost wholly to this formation. As a result, somewhat different conclusions as regards origin were reached, and two other theories were proposed—the lateral secretion, or segregation theory, and the replacement theory, which are, in reality, practically one as regards the source of the mineral. Mr. Winslow, in his Report on Lead and Zinc in Missouri, Vols. 6 and 7, states, in substance, his belief that the ores primarily associated with the primitive Archæan rocks were distributed through the sedimentary rocks which formed as off-shore deposits on the old Archæan shores, and that, by a long continued decay of these sedimentary rocks, they have been subsequently segregated into the water-ways, crevices and shrinkage cracks of the formations through which they were disseminated. He caused to be made a series of chemical analyses of limestone rocks, both in the vicinity of and distant from the ore-bodies of this region, and upon the infinitesimal amounts of lead and zinc which he says were found, he bases his theory of lateral secretion, or segregation. Such infinitesimal quantities of these minerals were found in his analyses, that one might almost, with equal justice, claim that they were the results of impurities either in apparatus or reagents. The presence of large amounts of dolomite, marcasite and baryte in the gangue are not satisfactorily accounted for. Furthermore, the occurrence of several more or less parallel and closely approximate ore-bodies, from 40 to 60, and, in one case, 100 feet wide, found in Joplin and Webb City, would preclude, it seems, the possibility of any such view of lateral secretion. Lead and zinc ore, in closely associated veins, have been traced from their

association with granite almost continuously up to the Upper Burlington. These two ores, galena and sphalerite, in an impure condition, are found in connection with granite in a vein at Decaturville, in Camden county, Missouri. At the Lang mines, in Christian county, in a high bluff of Upper Burlington limestone, a broad vein of lead and zinc, a brecciated ore-body, is exposed from the surface near the summit of the bluff, down to the contact of the Upper Burlington with the Lower Burlington, where it is immediately contracted to a narrow six-foot vein, passing through about 60 feet of the compact and hard rocks of the latter formation. At the foot of this horizon it again contracts to about two feet in width, where it passes through the Chouteau at the foot of the bluff. A shaft on this vein at the foot of the bluff passes through the successively contracting and expanding ore-body as it descends through the Hannibal, Louisiana, Devonian, First Magnesian, First Sandstone, and into the Second Magnesian limestone. Such a crevice can hardly be regarded as a gash vein or a shrinkage crack, or one that has been filled by decay and segregation from adjacent rocks. In studying the deposits of the Southwest, many other cases could be mentioned where the continuity of these veins may be seen through a number of formations, from the Upper Burlington through to the Magnesian series. The continuity of these veins is not limited in length or in depth. We are indebted to Dr. W. P. Jenney for the first thorough study and comparison of the magnesian deposits of Arkansas and southern Missouri with the Upper Burlington deposits, and for the first suggestion, since Featherstonhaugh and Swallow, of the deep origin of these deposits, which he ably advocated in the "Transactions of the American Institute of Mining Engineers," Vol. XXII, p. 171. Posepney also advocates this view of the origin of ores in the same "Transactions," Vol. XXIII, p. 179. Emmons, in Monograph XII of the United States Geological Survey, "The Geology and Mining Industry of Leadville," proposes a third theory which is advocated by Professor Kemp in his "Ore Deposits of the United States," viz.: the Replacement theory, according to

which he belives that the ore-bearing solutions have replaced the rock, molecule by molecule, thus forming an ore-body which has no well-defined walls, which does not presuppose an already formed cavity or fissure, but which insensibly merges into the formations on either side. This subject of the origin of the ores can best be grasped from the comparative study of the Magnesian limestone with the Upper Burlington deposits, and their relation to similar deposits in other countries. No one can compare the great Bleyberg mine in Belgium, described by Phillips in his "Ore Deposits" as a modified fissure vein, with the Joplin or Webb City deposits without being struck by their close similarity.

The lead and zinc mines of the world are mainly confined to the Silurian and Lower Carboniferous formations, and the consensus of the best European geologists and mining engineers is in favor of the deep seated origin of their ores. The presence of crystals of ore in the interior of fossils; the evidence, in many instances, that the ore has been deposited under great pressure, as so beautifully exhibited in the Pierson creek mines; the continuity of veins both in depth and a great distance horizontally, and their frequent association with faulting, together with the facts above mentioned, are strong evidence of the deep origin of our own lead and zinc. It has been shown that heated alkaline waters, under pressure, holding metallic sulphides in solution, would precipitate these on release of pressure and the precipitation of alkaline salts. Cooling would also bring about the same results. A slight change of pressure in different parts of the vein might cause a change in the deposit, and thus account for the different kinds of ore at different levels. It has been suggested that the heat necessary for these phenomena might have been produced by the Ozark uplift.

It is quite probable that ores are being redissolved and reprecipitated in cold solutions in mines to-day. In reopening an abandoned shaft at the Pierson creek mines, several four-inch spikes that were in a ladder which was submerged in water for, probably, about five years, were covered to a thick-

ness of half an inch with crystals of sphalerite. These are now in the collection of the writer.

THE BROOKLINE MINES.

At the present time, mining is not very actively carried on in the vicinity of Brookline. Until recently, work has progressed by shallow diggings in ground that has been gone over in a similar manner two or three times, and directly over an ore-body, the width of which is at least 50 feet, and the workable depth in the Upper Burlington limestone of more than 205 feet, as shown by a recent drill-well section.

The Potter Shaft. Of the mines, which are in three groups, the oldest and most worked is on the Potter tract, Tp. 28 N., R. XXIII W., Sec. 2, Se. ¼. Mineral was discovered here, if the information is correct, in about the year 1873. The claim has been extensively mined to depths of 25 to 50 feet. Mr. Bay Wilson worked this tract for lead from 1875 to 1876, taking out, it is estimated, over 300,000 pounds of ore, entirely supplying his own smelter which was built near by. One shaft was sunk to a depth of 95 feet. In others, drifting was extensively resorted to, but as both the shafts and the mines were so dangerous from constant caving in that it was impossible to work them properly, they were finally abandoned.

In the deepest shaft a run of blende three feet in thickness was struck. The ore-bodies are evidently wide, but it is impossible to estimate their extent from the surface. From observations on the shafts and caved in drifts, the crevice courses appear to run north 20 to 30 degrees east. The galena is associated with an abundance of calcite, dolomite and clay. The chert in the vein-stuff is but little brecciated, and the limestone of the wall-rock is soft, porous and highly fossiliferous.

In 1837, some Brookline people clubbed together and sank what was called the citizens' shaft to a depth of 85 feet on this tract. Digging was stopped in open ground, in decomposed

limestone with tallow clay and calcite.* About 60 feet to the north and west of this is located the "Line" shaft, so-called from its position on the line between two companies who used it in common to work their drifts. The Stogsdale company drifted north 44 feet, and took out the largest amount of lead on the tract. A little west of due north from the "Line" shaft, the old smelter was located. One hundred and eighty feet due north of this same shaft, Bay Wilson sank a shaft 93 feet deep, passing through bowlders and clay to a depth of 70 feet, and struck the first zinc at a depth of 86 feet.

The Armstrong Diggings. Immediately south of the Potter place is a second group of mines. In the north part of the "eighty" are some large sinks, with cave openings in the bottom, in one of which a considerable deposit of ore was found. Just to the west of these sinks, Mr. Armstrong, in 1875, discovered crystals of lead in the soil at the surface. A number of shafts were sunk, and over 5,000 pounds of zinc silicate were taken out. The old shafts, however, have been filled up.

The Old Silicate Diggings. About one-quarter of a mile to the south, but still on the Brown "eighty," is a group of excavations which were worked in 1875. Through the ignorance of the superintendent, instead of sinking shafts in the ore-body, which is from 50 to 60 feet wide, several were put down just outside of the ore-body in barren limestone. Subsequently, all the diggings were abandoned.

The Deputy Diggings. East and south of the Old Silicate diggings, on the Deputy land, Tp. 28 N., R. XXIII W., is another group of mines. Here considerable work has been done, and dry bone and silicate taken out.

The Pierson Creek Mines. The mining of this group is controlled to-day mainly by the Bowyer & Co. and the Lewis mining companies.

Nathalie Mine. The land upon which this mine is located is owned by a Mrs. McFarland, who leased eighty acres several

*This shaft was subsequently reopened and excavated to a depth of 125 feet. A powerful stream of water from the northeast stopped the work. The bed of clay and water-worn gravel in the bottom of the shaft was probed five feet further, but no change in conditions found.

years ago to Messrs. Ball and Thomas of Springfield. Early in the spring of 1890, these persons subleased it to Sherman and Edgar, who, in November, 1892, transferred their interest to the Nathalie Mining Company, which, after operating the mines about eight months, sold their lease to Mr. R. P. Bowyer. Mr. Bowyer systematically and successfully worked this mine until January, 1895. His drifting amounted to about 1,200 feet along the ore-body. A peculiar feature of this mine was a series of faults in the ore-body. In following the northwesterly trend of the crevice, a blank wall would suddenly be reached, and on drifting from 15 to 30 feet to the west the continuation of the crevice would be found. Five of these displacements were encountered in drifting across the eighty-acre tract. Over fifty thousand dollars worth of ore was taken from this mine. Fifteen per cent. of the bulk of this ore was galena.

These mines were well equipped with steam hoisting plants and concentrating works. They are situated in a narrow valley, mainly on the west bank of Pierson creek, not far from its junction with the James river, in Tp. 29, R. XXI W., Secs. 35 and 36. The east side of the creek is a precipitous cliff from 80 to 100 feet high. The western bank forms a gentle slope toward the Upper Burlington plateau to the northwest. The Kansas City, Fort Scott and Memphis railroad passes down the valley, crossing the creek just south of the principal mines.

This mining camp is one of the most instructive points for the study of ore crevices and depositions, and their relations to geological horizons. The section given below will show the formations at this point. It is taken from the top of the bluff on the east side of the stream and just north of the master-fissure of the group, at Mr. Bowyer's Sunrise shaft, the fissure being, at this point, associated with faults in which the hanging-wall is 20 feet higher than the foot-wall, the reverse of the general rule for faulting. The course of this master-fissure is about N. 35° W., having a dip of about 60° Ne. The bluff is capped with 10 to 20 feet of residual Upper Burlington chert:

Section of Bluff on Pierson Creek.

		Feet.
5.	Chert, residual, Upper Burlington	20
4.	Limestone, Lower Burlington	60
3.	Limestone, Chouteau, which extends 6 feet into the shaft	30
2.	Shales, Hannibal, the ore horizon	40
1.	Sandstone, Phelps, with fish teeth, forming the bottom of the run of mineral in this camp	½

This fault shows the formations on the south side of the ore-body 20 feet lower down than those on the north side. Along the bluff a few hundred feet to the north is another fault, and still a third is found about 100 feet further in the same direction. Owing to the slope of the Lower Burlington chert, it is difficult to determine, accurately, the throw of the last two displacements. They vary from 10 to 20 feet in the amount of dislocation. The disturbance of the strata caused by this faulting has deceived, and rendered the calculations of the miners worthless, as to the locations of the ore horizon at a number of points in their vicinity.

Returning to the main crevice, a number of shafts have been sunk from the top of the bluff along the fault, and the narrow ore-body has been exposed in the Lower Burlington limestone, midway along the bluff, thus presenting the very best opportunity for the study of the fault, the fissure and the worthless Lower Burlington ore-body which is about eight feet wide, the hard Lower Burlington chert of the ore-body is mixed with a small amount of disseminated lead and blende.

In the Chouteau, the ore-body apparently narrows, and contains but a little lead, in cubical crystals. As this is thickly covered with Lower Burlington slope, but little opportunity is given for its study.

In the main shaft in the Gumbo, or Nathalie mine, about 300 feet northwest from the old main shaft at the foot of the bluff, there is an excellent opportunity to study the deposition of the ore. The slope here is about 80 feet long, and varies in width from 15 to 30 feet. There are, apparently, at this point, two nearly vertical fissures separated by a narrow belt of nearly barren rock. The ore in the upper part of the shales is mainly

galena, in small cuboidal and modified octahedral crystals, disseminated in a white tallow clay lying in the shattered horizontal cracks of the shales. The lower 12 feet of the shales, which represent about the height of the slope, contains mainly zinc blende in the shape of thin, massive sheets intercalated between the bedding planes opened by the shattering, and leading, as veinlets, to the two main runs of mineral. These form the two nearly vertical veins before referred to. These shafts are frequently coated with the white, compact tallow clay referred to above. The blende is also found in small, disseminated crystals of great beauty in the softer shales. The vein-stuff consists of a very small amount of disseminated calcite ("tiff,") and the wall-rock is the typical blue or bluish-drab Hannibal shale.

The ore seems to have been deposited under considerable pressure, filling the two main crevices, and penetrating the shattered wall-rock in tortuous veinlets, filling such spaces in more or less massive sheets, and then forcing its way into the softer portions of the shale wherever it could penetrate, forming disseminated crystals. The blende is light colored, and is of great purity. The ore-body varies from 20 to 35 feet in breadth, and from 8 to 15 feet in thickness. The roof of the slope will, undoubtedly, furnish a great amount of galena when taken down. The ore is intimately associated with the "gumbo," a variety of tallow clay, from which it is separated with great difficulty, and the waste dump contains a considerable amount of ore.

The Bowyer and Company Mine. In the fall of 1895, Mr. Bowyer leased an adjoining 40 acres across the "Gulf" railroad right of way, on what would be a probable extension of the ore-body of the old Gumbo or Nathalie mine, in Tp. 29, R. XXI, Sec. 35 Ne. of Nw. The first drill that was put down struck the continuation of the ore-body. Several months were spent in prospecting with the drill, in order to demonstrate the extent of the ore-body on this new lease. In October, 1896, a shaft was sunk and mining commenced on this new tract. This ore-body, as was seen in the old Gumbo mine, lies between

the Hannibal shales and the Phelps sandstone. It is very irregular in shape, having a series of blind spurs running southeast from the main course of the ore deposit. This new ore-body has been developed for about 300 feet, and has a width of about 25 feet, with a thickness of 8 feet. This is one of the most intelligently managed mines in the southwest. The extent of the ore-body has been calculated by a system of both vertical and horizontal drilling, by the means of which latter new parallel crevices have been discovered. Of course only a diamond drill can be used for the horizontal drilling in the drifts. By utilizing the steam from the engine that runs the hoisting apparatus, the expense of running the diamond drill is only twenty-five cents a foot, while that of running the churn drill is reduced to seventy-five cents. The ore at these mines has always been extremely difficult to clean, owing to the fact that the disseminated crystals of lead and zinc are so closely associated with a tenacious white tallow clay. Mr. Bowyer has made a careful study of these conditions, and by means of some ingenious contrivances of his own, has managed to overcome the stubbornness of the combination, and to thoroughly and economically clean this ore, which was formerly so difficult to handle. His process requires 2,000 gallons of water per minute. The water is pumped from the creek, and is used only once. The concentrating plant consists of one Blake crusher, two revolving screens, four elevators, three sets of Cornish rolls and twelve plunger jigs. In order to control the water, two large double-rigged, ten-inch Cornish pumps, with a capacity of 12,000 gallons per minute, have been put in. The land on which this mine is located, is leased from Mrs. Greenlee, of Springfield, at 10% royalty. The wages paid at this mine are, for ground men, $1.75 a day, a nine hours shift; top men, $1.25 to $1.50 a day; foremen and engineer, $2.00 to $2.50 a day. The lead and zinc from the Pierson creek mines always bring the highest price in the market, as they are both of unusual purity. The output from the Bowyer & Company mine, as taken from the books, is as follows: From October, 1896, to January, 1897, 62,580 pounds of galena, and 303,400 pounds of

zinc blende. Owing to the severe floods of January, 1897, it was impossible to control the water until about May 1, 1897. From this date to November 1, 1897, the output was 195,380 pounds of galena and 1,154,680 of zinc blende.

The Lewis Mine. South of the Gumbo, or Nathalie, Mr. Bowyer did some prospecting in 1895, sinking the "Sunrise" shaft at the summit of the bluff just east of Pierson creek, but it was not until 1896, that productive mining was done east of the stream. In that year, Mr. J. T. Lewis leased from T. J. Kershner, the forty acres south and east of the Gumbo "forty," and about 800 feet east of the "Sunrise" shaft. The Lewis shaft is 84 feet deep, and the ore-body presents itself under, apparently, the same conditions as those which prevail at the Nathalie and Gumbo mines. At the present time the Lewis drifts have an extent of about 300 feet, with an estimated production of about 5,000 pounds of zinc and lead.

Suffolk Shafts. About one-half mile to the southeast of the Nathalie shafts are the mines of the Suffolk Lead and Zinc Mining company, which, at different times, have been called the Mumford or Kirshner mines, and later worked by Capt. Leader, of England. They were first opened by Mr. Kirshner, in 1886. They are located on the continuation of the crevices upon which the Phelps mines are situated, in Tp. 28 N., R. XX W., Sec. 1, Ne. qr. A low divide separates the two groups, which are only 200 feet apart. The following section, taken from the pump-shaft, gives the relative thickness of the geological formations at this point:

Section of the Suffolk Shaft.

		Feet.
5.	Soil	12
4.	Limestone, Chouteau	12
3.	Shales, Hannibal, (ore horizon)	30
2.	Shale, Hannibal, broken gumbo and ore	9
1.	Flint and Sandstone, Phelps and First Magnesian	8

As these mines are on the same crevice runs, they may be properly described in connection with the Phelps mines.

Phelps Diggings. The shafts here are mainly situated along two crevice courses about 75 feet apart, that run in nearly parallel lines from the James on the south, in a course north

25 to 30 degrees west through the ridge and the Suffolk diggings on its north slope. A section of one of the shafts shows :

		Feet.
8.	Limestone and chert, Lower Burlington, to top of ground at shaft	40
7.	Soil, made up of Chouteau and Hannibal	16
6.	Limestone, rather compact silico-magnesian, probably somewhat metamorphosed	12
5.	Sandstone, Phelps	2
4.	Limestone, King's Branch	14
3.	Alternating beds of hard chert and silicious limestone, First Magnesian	15
2.	Sandstone, First	3
1.	Shale, alternating layers of finely laminated blue and white	2

This shaft lies on one side of the crevice, and represents the geological horizons at this point. The main ore-body, at the Phelps mines, lies above the Phelps sandstones, the ore-body being made up of segregated mineral, disseminated through "gumbo," the wonderfully tenacious clay formed by the breaking down of the Hannibal shales. Great difficulty has been found in cleaning this ore by hand, as the peculiar gangue resists separation to a remarkable degree. Various experiments have been made as to the effects of frost and heat of the sun before hand-jigging, and it has also been roasted, but no method, so far tried, has given very satisfactory results until the Nathalie and Suffolk companies put in steam concentrators. Neither the King's limestone nor the First Magnesian, on account of their hard, silicious nature at this point, are favorable for the accumulation of much of an ore-body, and when the upper run of mineral is exhausted in all these mines, including the Pierson creek group, search must be made in the Second Magnesian for another run of mineral, and this is not promising, owing to the depth to be gone, and to the fact that the Second Magnesian ore-body is seldom more than eight feet wide. Hence, it would seem that all profitable mining in these camps is necessarily confined to the formations above the Phelps sandstones, viz.: the Hannibal shales.

The Phelps mines represent one of the oldest lead camps in the southwest. Schoolcraft* speaks of camping, in January, 1819, at a place which was, undoubtedly, this one. He says :

* A View of the Lead Mines of Missouri, Schoolcraft, 1819, p. 254.

"Finley river forms a junction with this stream (James), near the center of this choice body of land, and about one hundred miles above its mouth. Twenty miles above the junction of these streams, on the immediate banks of the James river, are situated some valuable lead mines, which have been known to the Osage Indians, and to some White river hunters, for many years. The Indians have been in the habit of procuring lead for bullets at that place, by smelting the ore in a kind of furnace made by digging a kind of pit in the ground, and casing it with some flat stones, placed so as to resemble the roof of a house inverted, such is the richness of the ore and the ease with which it melts. The ore has not, however, been properly explored, and it is impossible to say how extensive the beds or veins may prove. Some zinc, in the state of a sulphuret, is found accompanying it. There is not an inhabitant on all this stream. My own cabin, erected for a temporary purpose at the mines in January last, is the only human habitation within two hundred miles of that place."

The ore, occuring here in the soft Hannibal shales, is easily worked, and thus it is seen why the Indians, who are not fond of manual labor, should take such long journeys for the sake of procuring their lead with the least outlay of effort.

In 1844, Ex-Governor McClurg owned a store at Linn Creek, on the Osage river, from which point he distributed goods throughout the southwest. Hearing his teamsters speak of the discovery of lead at the old Hazelwood mines in Webster county, and at the Phelps mines, he told them to bring back ore, when they delivered their goods, as the price of lead was high at that time. He also set men at work at both of these camps, and he erected a small smelter at Hazelwood, to which point ore from the surrounding camps was hauled overland by team to St. Louis, a distance of over 200 miles. The price of lead soon declining, work at these mines was stopped for want of cheaper transportation facilities. The Phelps mines were abandoned until 1875, when the land was leased from its owner, Governor Phelps, by Messrs. Charles and Henry Sheppard, of Springfield, and Judge Picher, of Joplin. After some

general mining, the old pump-shaft was sunk to a depth of 60 feet, and by drilling 17 feet more. The best run of mineral was found at a depth of 25 feet in the lower "gumbo" deposit of the Hannibal shales, and above the Phelps sandstone. Search was made for a deeper run of mineral, but in vain, and the lease was soon given up. No further developments were made until 1885–6, when Mr. Joseph O'Donnel released it from Col. John E. Phelps. Mr. O'Donnel worked these mines profitably for about one year. In the latter part of 1886, Col. Phelps engaged a superintendent and worked the mines up to about 1891. In the early part of his work, the production was about two carloads of mineral per week.

ASH GROVE MINES.

The first discovery of lead in the region of Ash Grove was made soon after the first settlement of the county, in Tp. 30 N., R. XXIV W., Sec. 31. Only a small amount of "float" mineral was found. In 1859, in a well sunk on the Corum farm, one mile south of Ash Grove, near the center of Sec. 28, a small amount of galena was thrown out; but it was not until 1867 that any serious prospecting was done.

The mines in this locality are mainly confined to the sections lying south of Ash Grove, and east of the Sac river. From the first prospecting in 1867, by Judge Walker, up to the building of the railroad to Springfield, the mining industry of this region did not flourish, although many shafts were sunk, and a smelter built. It was the discovery of a rich prospect on the Hutchins land, where considerable mineral was taken out, that gave the real impulse to the development of the Ash Grove district. There were, however, great obstacles to successfully mining at this time. The pig lead had to be hauled 18 miles, over a rough road, to Brookline, the nearest railway station. The price of lead declined from $30 to $9 a thousand, the leases required the enormous royalty of 33⅓ per cent., and for these reasons mining was practically stopped until about 1888, when a rich strike was made on the Duncan land two miles south of the town.

The mines of this region are all located in the middle beds of the Upper Burlington, and most of the ore is taken out from just above a bed of yellow rock 30 feet thick, which is frequently mistaken for the Chouteau limestone. This yellow rock is the same that forms the floor of the lime kiln quarry at Ash Grove.

The following camps in the vicinity of Ash Grove will be briefly described:

Corum Diggings, Tp. 30, R. XXIV, Sec, 28, S. ½ center. More prospecting was probably done on this land than on any other in the region, and small amounts of ore obtained.

The Hutchins land, now known as the Murray tract. The mines on this land are situated a mile and a half south of Ash Grove, in Tp. 30, R. XXIV, Sec. 32, Se. ¼, Ne. ¼. They were discovered in 1867, and a considerable amount of ore was obtained from them, but owing to the discouragements already referred to, work was soon abandoned, and they were not reopened until 1888, when the rich deposit on the Duncan land, a quarter of a mile to the south was found. A number of shallow shafts have been sunk on this tract, and the accompanying section, obtained in 1893, gives a general idea of the succession of strata at this point.

The upper 15 feet in this section represent the residual material from a ferruginous sandstone, and in a number of shafts in the vicinity blocks of sandstone and shale are encountered above the limestone. The lower 10 feet represent the upper third of the thirty feet of yellow rock which has so frequently been confused with the Chouteau. The first zinc from the Ash Grove mines was shipped from this tract. Of the various companies organized to develope this land may be mentioned the Golden Eagle mining company, with a capital stock of $30,000, which took out about 400,000 pounds of lead; the "Gulf" company, which found good silicate at a depth of 65 feet; and the "Clinton" company, which also found a fine deposit of silicate at 65 feet.

Taylor shaft, on the McCord land (Tp. 29 N., R. XXIV W., Sec. 6, Ne. qr.), about one-half mile south of the Murray

land, Taylor and Edgington discovered a rich deposit of mineral on this land in 1889. The shaft was sunk to a depth of 75 feet, after passing through, at the surface, about 15 feet of ferruginous sandstone. The output of this shaft from February to May, 1890, sold for $23,000.

Dunlop Shaft. On the lot adjoining the Taylor and Edgington shaft, Dunlop and McKellop struck a rich vein of silicate at 80 feet. At the present time, 1896, this is the only tract worked in the Ash Grove district. The Gilliam mining company have sunk several shafts on this tract, and have done some drifting, the deepest point reached being 135 feet, all in bowlder formations. The deepest run of mineral, however, is at a level of 85 feet, just above the yellow rock. The ore-channel has a course N. 14° W. The ore-body varies from 15 to 60 feet in width, and is from 6 to 7 feet high. Upon this ore-body drifting has gone on 600 feet. The ore consists mainly of galena in the upper part, followed by zinc silicate, and with zinc blende in the lowest run. Little or no dry bone is found.

The Pennsylvania Company Land. This is situated just east of the railroad and south of the town of Ash Grove, in Sec. 28. This company sank a shaft, in 1895, to a depth of 250 feet, reaching the First Magnesian limestone. Mr. Winslow gives the following section:

Surface, red clay and chert fragments.

Open ground, consisting of red clay and chert fragments, the latter loose or cemented by hard, drab, earthy quartzite, in which are crystals of galena; in this cerussite was also found.

Limestone, yellow, with clay pockets and perhaps some chert, close-textured, probably Chouteau, containing no ore.

Limestone, dark colored, coarsely granular.

Limestone, light gray, finer texture.

Limestone and chert, in very thin (4-inch) layers, the limestone fine-grained and dense. At 125 feet ore was found in thin sheets and in small pockets, with calcite, and at 175 feet, a little more.

Shale, drab, coarse textured, dense, slack on exposure.

Limestone, dark colored, coarsely granular, growing finer in texture and more arenaceous toward the base. Contains some pyrites.

Quartzite, calamine near the top, somewhat colored, containing desseminated blende.

Sandstone or quartzite, white, with vertical veinlets of blende and some galena extending from top to bottom.

Shale, dark calcareous, passing upward into the sandstone.

Shale, almost black, arenaceous, lower half contains ore in pockets or vugs in crystals, and associated with no clay. Much water flowed from the stratum.

Magnesian limestone, light-gray colored and porous; probably Silurian.

Section of Pennsylvania shaft.

As before stated, most of the ore in the different camps is obtained just above the yellow limestone, No. 4 of the section, though at times it extends to greater depths, and is geologically lower.

The Getty Diggings. They are "in the Nw. ¼ of Sec. 33, Tp. 30 N., R. XXIV W. A number of shafts had been sunk to a depth of from 20 to 30 feet, penetrating the yellow limestone 6 to 8 feet. Both galena and calamine were taken out."

Twenty years ago, Professor C. P. Williams wrote substantially, as follows:

"On section 28 a number of shafts have been sunk, the deepest of which was carried down to the depth of 50 feet. The lead ore was struck at from 15 to 30 feet from the surface. Superficially the ore was mainly carbonate of lead of the variety known as the "ash mineral," but in depth the galenite predominated. The ore was intermixed with clay, flint, limestone and "quartzite," and occupied irregular cavities in the limestone. In carrying down the deepest shaft about ten tons of mineral were taken out. At another shaft 183 feet southwest from the first mentioned, the product was 25 tons. Several diggings west from the last named, a distance of 115 feet, a third shaft, carried to the depth of 45 feet struck galena, or blue mineral, at a depth of 30 feet. Three hundred feet from

this shaft, on a course S. 28 deg. W., a shaft 19 feet showed "cog" and "dice" mineral, intermixed with flint and calcite, the latter chiefly of the variety known as dog-tooth spar. In drifting 10 feet from this shaft, with an opening three feet high by about four feet wide, between 5,000 and 6,000 pounds of galena were removed. A section of this shaft exhibited the following (figure):

Soil and gravel, with limestone and chert fragments.

Red clay, with many chert fragments.

Clay and ocher, with much limestone, and with patches of "tallow clay," carrying some cerrussite.

Limestone, soft magnesian, coarsely granular, with much calcite and dolomite, and carrying galenite.

The rock beneath this last is close-grained, compact, and somewhat silicious limestone, of blue color, containing 41 per cent. of magnesium carbonate, and is generally regarded as the bed rock of inferior limits of the lead-bearing zone."

PICKEREL CREEK MINES.

These mines are located at the head of a spring branch, which is one of the tributaries of Pickerel creek, and on a dividing ridge running southeast from the spring. They are in Tp. 29 N., R. XXIV W., Sec. 33, Ne. qr., and Sec. 34, Nw. qr. They were discovered in 1887, by John McDaniel, who found some small crystals of lead when cleaning out the spring, and they were opened and worked somewhat extensively for several years by Thomas O'Banon, being finally abandoned because of lack of transportation facilities. Ash Grove, the most accessible point for shipment, is about 14 miles distant. The condition in which the ore is found in these mines is almost identical with that at Ash Grove. The large bulk of the ore is taken from the decomposed beds immediately above the yellow rock, or Chouteau-like layer of the Upper Burlington limestone. Some 200 shafts have been sunk at these diggings, only two or three of which extend below the yellow rock above referred to. These shafts are mainly located along three more or less parallel runs that have an average course of 25° north. They

extend for about one-third of a mile, and are only a short distance apart. The west run is almost wholly located in the northeast corner of section 30, while the other two are mainly in the northwest corner of section 34. A shaft sunk to the depth of 40 feet near the middle of the west run struck the yellow rock at a depth of 25 feet. A crevice 6 feet wide in this limestone was exposed, having a course N. 20° W., and was filled with chert and galena. Above this limestone several drifts were made in the clay, and a large amount of "float" lead (galena) was taken out. Below the yellow rock, a pinkish, highly crystalline arragonite, commonly called cave onyx was found. The deepest shaft sunk was near the spring in the northwest corner of the diggings. It was 62 feet deep, and passed through two feet of soil, 6 feet of the yellow rock, and 54 feet of blue, crystalline Upper Burlington limestone. The barometer, from the mouth of the shaft to the exposure of the upper part of the Lower Burlington, two miles away, indicates a thickness of 130 feet of Upper Burlington. Some zinc was found in this shaft, while "float" lead was found up the slope in all three runs in clay just above the yellow layer, and dry bone (lead carbonate) was found near the surface at the highest points on all these runs. Some silicate was taken out of the middle run high up the hill. Crystals of galena, dolomite and zinc blende are mixed together with the chert bowlders in some of the shafts. Phosphate of lead was associated with "tiff" and galena at a few points. In a shaft 46 feet deep at the top of the hill a flat opening above the yellow rock yielded 60,000 pounds of "float" lead. A peculiar sandy, porous rock is associated with the mineral at a number of points. The porous cavities are, evidently, the casts of zinc blende crystals that have been eroded away. Black oxide of manganese moss markings are frequent in the flint, which is white, seamed and slightly fossiliferous. The ore-body, in places, seems to have a width of nearly 100 feet. It is estimated that over 200 car loads of mineral has been taken out of both the central and western runs. S. M. Smith, of Springfield, has recently reopened these mines.

Professor Williams visited these mines in 1878, and his notes are essentially, as follows:

"Ten miles nearly due southward from Ash Grove, the lead-bearing members of the Keokuk series constitute the surface rock, and are worked for lead ores. The diggings are chiefly in the northern part of section 33, township 29 N., R. XXIV W., in the vicinity of Pickerel creek. The ores occur at the same horizon as at Ash Grove, and the conditions of the latter are very closely reproduced at Pickerel. The diggings are near the summit of a hill, which attains an elevation of about 45 feet above the ravine at its base, or 190 feet above the Pickerel at the crossing of the new road from Springfield to the Chalybeate springs of Lawrence county. The mineral is struck at depths ranging from one to 26 feet. It occurs mixed with chert and limestone pebbles, in a dark red or yellowish clay, non-plastic and ochreous, with patches of non-plastic, or "tallow" clay. Limonite ore is found in patches and seams. Much of the ore thus found has been "dry bone," "ash mineral." From three prospects nearly 12½ tons of mineral were taken. The ore is hauled to Ash Grove, a distance of 10 miles as stated, and is treated at the furnaces at that place. The "bed-rock" resembles closely that reached at Ash Grove (the yellow Chouteau-like rock), and does not differ from it very widely in composition, as is shown by the annexed analysis of a specimen:

Calcic carbonate	54.584
Magnesic carbonate	41.099
Ferric oxide and alumina	1.480
Insoluble silicious matter	2.523
	100.046

Some 4,000 tons of ore are reported to have been hauled from here to Ash Grove.

THE ELK VALLEY DIGGINGS.

These are owned by Mr. L. C. Lee & Co., of Springfield, and are located in Tp. 27, R. XXI W., Sec. 33 S. ½ of Ne. , and the N. ½ of Se. ¼. They are a fine example of mines situated in the lower beds of the Upper Burlington. Here are

found a large number of parallel crevices from 40 to 200 feet apart, which run across a small dividing ridge that separates Elk Valley from the plateau on the north. Numerous shafts have been sunk along these crevices from the valley of Elk creek right over the ridge, outlining, very perfectly, the location of the different fissures. These crevices have a compass course of N. 25 to 28 deg, W. The ridge is capped by about 80 feet of Upper Burlington limestone, the Lower Burlington outcropping in the Elk Valley. The ridge is quite narrow, and the workable deposit is confined to the Upper Burlington. The shafts vary in depth from 60 to 100 feet, the deepest extending down into the Lower Burlington. As a rule, galena was found in the upper runs, silicate in the middle, and blende in the deepest runs. Several rich deposits were found in flat openings, which are horizontal cracks between the bedding planes of the limestone.

No accurate statement of the production of these mines could be obtained, but from the data given, 80,000 lbs. of lead and 100,000 lbs. of zinc, mainly in the silicate, would be a small estimate. One crevice in the north part of the camp has been opened as a shallow trench along the slope of the hill, very beautifully exposing the vein and veinlets. The ore taken out at this point was mainly zinc blende, lying in the lower layers of the Upper Burlington, but a few feet above the Lower Burlington. It was light colored, finely crystalline and granular, and disseminated through the vein-stuff in the main crevice. The main fissure was but two or three inches wide; the ore body about 20 feet wide. There was probably 20% of ore exposed in the face of the ore-body, in the veinlets and disseminated in the rock.

THE NEW ALMA MINES.

East of the Lee mines are situated the Weaver, the New Alma, the Old Alma, the Ozark mining company and the Miller mines, all of which have been worked at intervals, for the past forty years. It has been estimated that as much ore has been taken from along this valley as from all the mines of

Christian County put together. The most important, and the only one of these mines worked today, is the New Alma, about 800 feet north of the old Alma mines, in Tp. 27, R. XXI, Sec. 36, Sw. corner. This deposit was first discovered a few years ago by Mr. Weaver, and is now worked by Col. John E. Phelps, of Springfield. The main shaft is about 80 feet deep, and situated in the lower beds of the Upper Burlington. From the bottom of this shaft upward, there is an ore-body with a vertical face of about 25 feet. Drifts have been extended in different directions, and indicate a total width of the ore-body of over 35 feet, no wall-rock having been found on either side. The course of the vein is about N. 20° W. Prospecting in the immediate neighborhood indicates a considerable extension of this crevice. The ore-body consists of a coarse, rather loosely aggregated breccia, of a compact chert with bluish clay and lead. The clay, which contains the lead, frequently assumes a thin, layer-like deposit. An irregular seam-like deposit of a fine pink tallow clay forms a horizontal layer about 12 feet above the bottom of the shaft. Some zinc silicate and blende are found in the lower layers of the ore-body. The ore is mainly galena, irregularly disseminated in small fragments or crystals through the loosely aggregated gangue. The ore-body, where exposed, averaging about 50% of ore, is worked with great ease, requiring but little blasting. A stream of water has been encountered which requires a very strong pump to control. The capacity of the mine, in the spring of 1895, was about 3,000 lbs. of cleaned lead per day. The total output, as near as could be learned, was about 200,000 pounds.

THE HORNBEAK DIGGINGS.

These mines are situated in Tp. 27, R. XIX W., Sec. 36, Se. ¼ of Nw. ¼, and furnish an excellent opportunity for the study of a mine in the First Magnesian limestone in the process of being worked. These are but a portion of a large group of mines that were worked many years ago. They are situated on the western slope near the head of a narrow gorge or cannon, on both slopes of which a large number of shafts have been

sunk. The barometer gives a thickness of certainly over 100 feet for the First Magnesian, if the doubtful upper bed of laminated "cotton rock," the probable position of which has been discussed in the chapter on Magnesian Limestones, is included. At the main shaft in the Hornbeak mines, the following section is obtained:

		Feet.
11.	Laminated "cotton rock," the doubtful bed discussed under the First Magnesian	10
10.	Bluish-black chert, full of galena	1
9.	Oolitic "cotton rock"	10
8.	Black chert, with galena	1
7.	Dark brown, compact magnesian limestone	8
6.	"Sand flint," sandstone and chert	1½
5.	"Cotton rock"	10
4.	"Spotted cap," a dark grayish mixture of blue flint and silicious magnesian limestone, the latter porous, with small irregular cavities filled with yellowish, less indurated material, the typical First Magnesian of the northern part of the area. (One other shaft, lower down on the slope, extends considerably deeper than this main shaft, and from it may be added the following beds, beside those already given:)	
3.	Very hard silico-magnesian limestone	10
2.	Compact, yellowish-gray, magnesian limestone, with moss markings of manganese di-oxide	8
1.	Bluish chalcedonic flint. According to barometric readings, this extends down to about the First sandstone.	1

In all the mines in this vicinity, as far as investigation has gone, the ore found in the First Magnesian limestone is mainly galena, though a little zinc silicate has been found in the Hornbeak shaft. Zinc blende is confined almost wholly to the middle and lower beds of the Second Magnesian. The ore-body in the First Magnesian, rarely, if ever, exceeds 15 feet in width, conforming more or less decidedly to particular beds in this horizon. The first run of mineral is always found near the surface, and results from the segregation of material from the decomposed superincumbent beds. The early mining was almost wholly confined to such deposits, and a large amount of "drop" or "float" galena has been obtained. The "cotton-rock" and silico-magnesian limestone are, ordinarily, more or less destitute of an ore-body, the narrow crevice filled with ore passing through them. This accounts for the abandoning of many tracts to the north, in Webster county and elsewhere, after the superficial deposits had been taken out.

In the Hornbeak shaft, beds No. 2 and No. 4 are very rich

in ore. In these flint beds, the galena has penetrated for some distance on each side of the crevice in flat, irregular crystaline sheets, varying from one-half inch to over an inch in thickness, cementing together the somewhat flat, shaly, irregular layers of flint, and forming a very peculiar breccia. The next run of mineral is in bed No. 8, what the miners call the "spotted cap." The porous nature of this rock, and its brittleness, all tend to form favorable conditions for the deposition of ore; and in this bed, in cracks and crevices extending from the ore-body some little distance on each side, and immediately below it, is found one of the valuable runs of mineral. The last rich deposit is usually immediately above the First sandstone, in what the miners term a "clay opening," this representing the unconformity between this horizon and the first sandstone referred to in the chapter on the First Magnesian limestones. There is very little gangue associated with the ores in this horizon, and only a little calcite. Some fine specimens of *Straparollus* have been found in the "spotted cap" bed in this camp. The course of the fissure is N. 18 deg. W.

These mines were discovered in 1854 or 1855, by Mr. R. V. Purdom, if the information given is correct, and Mr. Hornbeak estimates that over 100,000 lbs. of lead, and but very little zinc, has been taken from the shafts in this camp.

FAIR GROVE MINES.

Bull Winkle Diggings. None of the mines of the lowest ore horizon, the Second Magnesian are at present worked in this area. The most reliable information has been obtained respecting the Bull Winkle or Bass mine, in Tp. 31, R. XXI W., Sec. 25, Nw. ¼ of Se. ¼, and a brief description of this mine will be given, not because of its productiveness, but because it is a good type of one of the worthless deposits in the northern half of the district. Ore was first discovered at this point about 1873, in the gravel of a small gully. Messrs. Appleby, Bechtell and Parce, of Springfield, commenced work here in September, 1890. In their first shaft, the first residual deposit of ore was found near the surface imbedded in clay. The Second Magnesian limestone, forming the wall-rock of the

crevice, was struck at a depth of 8 feet. The crevice had a course of N. 40 deg. W., and varied from a few inches to 18 inches in width. The walls of the crevice were coated with flatened crystals of lead, and the ore-body contained disseminated ore with but little calcite. This shaft was sunk to a depth of 24 feet. Their deepest shaft, after sinking to a depth of 30 feet, was drilled 105 feet further, passing through "cotton rock" and flint, all in the Second Magnesian limestone. The shafts were started in the upper beds of this formation. About 1,200 lbs. of lead ore have been taken from these mines.

In Webster county, especially in Panther Valley, the mining done in the Second Magnesian within this area was quite extensive in early days. Large tracts in that vicinity are now covered with abandoned dumps and half-filled shallow pits. Zinc blende was then considered worthless, and when the galena, which is confined to the upper portion of the Second Magnesian was exhausted, the mines were abandoned. The remains of an old smelter can still be seen in Panther Valley, on the farm of Mr. Oliver Ewing, in Tp. 29, R. XIX, Sec. 34, Nw. ¼. The old boarding-house put up for the workers in the mines is still standing on the farm of Wm. Gates, in Tp. 28, R. X1X W., Sec. 3. Spasmodic attempts have been made at various points, during the past few years, to reopen these mines for zinc, but lack of capital, and proper pumping facilities, as well as difficulties of transportation, have prevented any good results.

MINOR MINES.

In addition to the mines already described there are a number of localities where ore has been found and some prospecting has been done, resulting in the production of a few hundred pounds of galena. These diggings are mostly a few miles east of Ash Grove and north of Bois d'Arc, on Clear creek. In the neighborhood of Graydon Springs, also, a few pits have been dug, from which "float" lead has been obtained.

A list of locations at which lead and zinc ores have been mined or found within the area is here given. It has been the endeavor to give all authentic information, so far as obtainable.

NO.	Name of mine or owner.	County.	Section, township and range.
1	Henry Sherman	Webster	Se., Ne., Ne., 10, 28, 19
2	Wm. Gates.	"	Nw., 3, 28, 19.
3	"	"	E. ½ Sw., 3, 28, 19...
4	"	"	Sw. ¼, 3, 28, 19
5	Old Lunke Diggings (Devil's Den)	"	Ne., Nw., 3, 28, 19...
6		"	23 and 24, 29, 19
7	Harper Mine	"	Se., Se., 33, 29, 19
8	Oliver Ewing	"	Sw., Nw., 34, 29, 19..
9	F. M. Johnson.	"	Sw., Nw., 27, 29, 19..
10	" "	"	Ne., Ne., 28, 29, 19...
11	T. McClelland	"	9, 29, 19
12	T. S. Florence	"	Middle, 4, 29. 19
13	Mrs. Welch's	"	E. ½ lot S., Nw., 4, 29, 19
14	Panther Valley	"	22, 29, 19
15		"	Nw., 1, 29, 19
16	C. H. Welch	"	Sw., 18, 29, 19
17	Northview Mining Co	"	Ne., Nw., 26, 30, 19..
18	Bodenheimer Mound	"	Nw., Sw., 9, 30, 19..
19	Dr. E. T. Roberson.	"	Nw., 19, 30, 19
20	B. F. Spencer	"	Sw., 15, 30, 19
21	Moore	"	Sw., Se., 15, 30, 19...
22	John Hornbeck	Christian (Swan Cr.).	Se., Nw , 36, 27, 19 ..
23	Purdom Diggings	" "	Ne., Sw., 36, 27, 19 ..
24	Burkhart & Co	" "	Nw., 36, 27, 19
25	O'Haver	" "	Se., Nw. 35, 27, 19
26	Hard Scrabble	" "	Nw., Nw., 36, 27, 19.
27	McGregor Shaft	" "	Nw., Se., 36, 27, 19 ..
28	Talman Mine	" (Finley creek)	Ne., Nw., 7, 27, 19...
29	" "	" "	Se., 6, 27, 19
30	Plummer Shaft	" "	Se., Sw., 10, 27, 19...
31	Finley Creek Mining Co	" "	Nw., Ne., 15, 27, 19..
32	Talman Shaft	" "	Ne , Ne., 12, 27, 20...
33	Bannister Tract	" (Swan creek)	Nw., Sw., Se., 36, 27, 21
34	Elk Valley Diggings	" (Elk Valley)	S½, Ne, N¼, Se, 33, 27, 21

Condition.	Geological horizon.	Course of crevice.	Production.	Date of discovery
Prospect...	Burlington.....	N., 20° W.....	Lead prospect	1889
Abandoned.	Second Magnesian	N., 20° W.	Large amount galena.	1888
"	" "	N., 20° W.....	" "	1888
Prospect...	" "	N., 20° W.....	Prospect	1860
" ...	" "	N., 20° W.....	"	.....
"	" " ?	....	"	.....
Abandoned.	" "	N., 35° W.....	Large amount galena.	1878
"	" "	N., 20° W	" lead & zinc	1886
"	" "	.....	" lead.....	1846
"	" "	.....	" lead & zinc	1846
Prospect...	First Magnesian ..	N., 70° E.....	Small am't (1,000 lbs.) lead and zinc	1860
"	" " ..	.....	Prospect	.....
"	Second Magnesian	N., 32° W.....	"	.....
"	" "	....	"	.....
"	....	.....	"	.....
"	Second Mag. ? .	.....	"	..... .
"	First Magnesian ..	....	. .....	.....
"	" " ..	.....	Prospect	....
" ...	" " ..	.....	"	.....
"	Second Magnesian	.....	"	1891
"	" "	....	"	1891
Worked	First Magnesian...	N., 18° W.....	100,000 lbs. lead; little zinc	1854-5
"	" " ..	N., 18° W.....	800,000 lbs. lead.....	1854-5
Abandoned.	" " ..	.....	50,000 lbs. lead.....	.....
"	" " ..	N., 20° W.....	100,000 lbs. lead	1855-6
"	" " ..	....	50,000 lbs. lead.....	....
"	Burlington.....	... .	Worthless.....	1891
"	First Magnesian...	.....	Prospect	.. ..
"	.....	....	"	.....
"	First Magnesian...	N., 20° W.....	....	1888
"	" " ..	.....	....	1890
"	.....	....	....	.....
"	Cherokee.....	N.....	2,000 lbs. lead.....	.....
Not worked	"	N. 25°, 28° W....	100,000 lbs lead, 80 000 lbs, zinc, sil	..... ?

NO.	Name of mine or owner.	County.	Section, township and range.
35	Cowlick Dakota	Christian (Elk Valley)	Nw. 33, 27, 21
36	M. D. Williams	" (Republic)	Se., 20, 27, 23
37	Reynold's Shaft	" "	Nw., Sw., Sw., 7, 27, 23
38	John Ray	" "	Sw., Ne., 8, 27, 23
39	Wommack Prospect	Webster	Nw., Nw., 17, 30, 19
40	Dishman "	"	Sw., Nw., 18, 30, 19
41	Wommack "	"	N. ½, Se., 8, 30, 19
42	Phelps Mines	Greene	Nw. and Ne., 1, 28, 20
43	Suffolk Mine	"	Sw., 36, 29, 20
44	Nathalie Mine	"	Sw., Ne., 35, 29 20
45	R. M. Jones (Fairbanks)	" (Strafford)	Center, 13, 29, 20
46	Appleby & Rutherford	" (N. Springfield)	Se.cor., Sw., Sw., 6, 29, 21
47	" "	" "	Ne., 6, 29, 21
48	Lewis McAdam Prospect	" "	Near N. line, 4, 29, 21
49		" (Strafford)	14, 29, 20
50	Smalstig	" (James Fork)	Sw., 15, 28, 21
51		" (Bois D'Arc)	Nw , Sw., 31, 29, 22
52		" "	Nw., Sw., 32, 29, 23
53		" "	Se., Se., 32, 29, 23
54	A. P. Harwood	" "	Ne., Ne., 2, 28, 23
55	Potter Mines	" "	Se., Se., 2, 28, 23
56	Armstrong Mines	" "	Ne., Ne., 11, 28, 23
57	Nixon Mines	" "	S. ½, Ne., 11, 28, 23
58	J. R. Williams	" "	Se., Nw., Se., 14, 28, 23
59	Deputy Mines	" "	Middle, W. ½, 12, 28, 23
60	Wilson Creek and Greene's Mines.	" "	N. ½, Se., Sw., 22, 28, 23
61	J. B. Lawrence	" (Springfield)	Sw. cor., 22, 29, 22
62	Ball Prospect	" (N. Springfield)	Nw. cor., 4, 29, 21
63	N. P. Grier.	" (Strafford)	Se., Ne., Ne., 24, 30, 20
64	Dr. Roberson Prospect.	" "	Ne., 24, 30, 20
65	Jos. H. Cash	" (Fair Grove)	Sw., Nw., Se., 32, 31, 21
66	Dr. Cowden Shaft	" "	Nw., Se , 29, 31, 20
67	Ball Winke Shaft	" "	Se., Nw., Se., 25, 31, 21
68	Kyle & Dawson	" (Bois D'Arc)	Ne., Nw., 32, 30, 23

Condition.	Geological horizon.	Course of crevice.	Production.	Date of discovery
"	N. 25°, 26° W.	...	Small am't lead & zinc	?
Abandoned.	"	...	Blende	1890
"	"	...	"Shines"	1890
"	?	...	...	...
Prospect	Second Magnesian	...	Prospect	...
"	First Sandstone	...	Float	...
"	Second Magnesian	...	Prospect	...
Not worked	V. Sh., 1st & 2d Mag.	N., 28° N., 35° W.	233,000 lbs. lead, 1,104,000 of blende	*
Worked	" "	N., 28° N., 35° W°	25,000 lbs. blende	1886
"	Vermic. shale	N., 35° W.	3,900,000 lbs. zinc, 430,000 lbs. pb.	...
Prospect	Burlington	...	Prospect	...
"	Cherokee	...	"	1891
"	"	...	"	1891
"	"	...	"	1890
"	Burlington ?	...	" lead	...
"	"	...	Shines	1885 ?
"	Cherokee	...	Prospect	...
"	"	...	Lead prospect	1890
"	"	...	"	...
"	"	...	Lead in a well	1885
Not worked	"	Ne. ?	809,000 lbs. lead	1878
"	"	Nw. ?	80,000 lbs. lead	1875
Worked	"	N., 35° E.	Large amount silicate	1875
Prospect	"	...	Galena in well.	...
Not worked	"	...	Drybone and silicate	...
"	"	...	Galena and blende	1884
Prospect	"	...	Galena	...
"	"	...	"	...
"	First Magnesian	...	"	...
"	" "	...	Zinc carbonate	...
"	V. Sh. & First Mag.	...	Disseminated galena.	† 1845
"	Second Magnesian	...	Shines of galena	1890
"	" "	N., 40° W.	1,200 lbs. lead	About 1878
"	Cherokee	N., 20° E.	About 800 lbs. lead	1890

No.	Name of miner or owner.	County.	Section, township and range.
60	Jesse Colter.....	Greene (Bois de Arc...	Nw., Se., 33, 30, 23 ..
70	G. W. Long	" " ...	Se., Nw., Ne., 31, 30, 23
71	G. B. Kyle	" " ...	Ne., Sw., Se., 29, 30, 23
72	Mrs. Treadham's	Polk (Graydon Spr.)..	Sw., Nw., 8, 31, 23...
73	John W. Mitchell	" " ..	1, 31, 23..... .....
74	Dr. Miller.....	" " ..	31, 32, 23 .....
75	W. H. Vestal	Greene (Burkly).....	Se., Sw., Se., 4, 30, 23.
76	....	Polk	Ne., 8, 31, 23 .....
77	....	Greene (Willard).....	Se. ¼, 27, 30, 22 .....
78	....	" (Bois D'Arc)..	Nw., Se., 30, 23.....
79	Baumgarten.....	Webster.....	Lot 7, Ne. ¼, 5, 29, 19.
80	Unknown diggings	Greene (Bois D'Arc)..	Nw., Se., 21, 30, 23 ..

*Old Indian mines, discovered by Schoolcraft 1819.
†Bedell's
‡ Very old mines, and remains of smelter.
§Very old; remains of numerous shafts.

Condition.	Geological horizon.	Course of crevice.	Production.	Date of discovery
"	Coal Measure.....	.....	Dissem. lead and zinc	1891
" ...	" ...	....	" "	1887
"	Cherokee.....	.....	Float lead.....	.....
"	....	....	"	.....
"	Secodd Magnesian	.....	"	.....
" ...	....	.....	"	..... .
"	Cherokee.....	....	Dissem. lead and zinc	1891
" .. .	.....	....	Shines	1891
Old mines..	Cherokee.	.....	Old shafts.....	‡
"	"	....	"	Very old.
Prospect ...	"	.....	Galena in traces	1885
Old mines..	"	....	Probably for Galena..	§

Limestone Quarry, Phenix.

Limestone Quarry, Phenix.

and the most beautiful of the building stones of this region. Usually, when free from chert the beds are very massive, and the blocks that are obtainable are limited in size only by the ability to handle them. The coarse, subcrystalline structure, the homogeneity of texture, and purity of composition of the middle beds make the rock an unusually fine stone for all constructional purposes. Ordinarily, only a bush-hammer dressing is necessary. The Drury College chappel, St. John's Episcopal church, and the foundation walls of the new government building, as well as the beautiful stone wall of the Confederate cemetry, in Springfield, are good examples of the fine appearance which this rock presents in use.

The principal quarries are in and about Springfield, but there are also numerous small openings. Many small quarries are also scattered through the county, but they are only worked roughly for lime and foundation rock. Systematic quarrying on a large scale has yet been carried on at only one place in the district, and this is at Phœnix.

Phœnix Quarries. These quarries are located near the town of Phœnix, in the northwestern part of the county. They were opened in 1888, in the middle of the Upper Burlington limestone. The plant is excellently equipped for working, handling and sawing blocks of all sizes. The quarrying capacity is 800 cubic feet a day. The beds at this point are remarkably compact and close-grained for this formation, and as they are worked only by sawing, the jar and strain produced by blasting, is avoided. The crushing test of this rock, determined by experts, employed by the company, is from 8,000 to 10,000 pounds. The compactness of the rock also insures great protection from weathering. The presence of the suture-joint, or "crow-foot," which is common in all beds of the Upper Burlington limestone of this region is neither a blemish nor a detrimental factor as experiments have shown that specimens containing the suture-joint give a high resistance to crushing. The uniform weight of this rock is remarkable, varying but a pound or two from 164 pounds to the cubic foot. There is practically an unlimited supply of rock at the point at which

the quarries are developed. The shipments of stone for the past two years have been about 65,000 cubic feet. Preparation is being made to increase the output to 100,000 cubic feet for the current year. This stone has been used to a considerable extent in Kansas City, St. Louis, Springfield and various points in Kansas, Arkansas, Texas and Tennessee. It has been mainly used for trimming, range work, sills, steps, flagging, bridge piers and general building purposes. It is susceptible of a fine polish, and is a handsome and valuable stone.

Brockman Quarry. This quarry is located about seven miles northwest of Springfield. It is opened in the heavy middle beds of the Upper Burlington limestone. A switch of the Bolivar branch of the St. Louis and San Francisco railroad could easily be run to this quarry for the transportation of its output.

Ash Grove White Lime Association Quarry. The quarry, located near the same company's lime works at Ash Grove, is one of the finest undeveloped properties in the state. A ledge 700 feet long, from 22 to 25 feet thick, without horizontal, and with few vertical seams has been exposed. At present, the rock is used only for the manufacture of lime, but it would be of the highest value for the production of dimension stone.

Lower Burlington Limestone. The layers of this formation are hard, rather irregularly bedded and often contain considerable chert. No quarries are opened in it, but it is often used locally when other stone cannot be as readily obtained.

Chouteau Limestone. This stone deserves a much wider use than it now has. Its beautiful buff color, the uniform thickness of the beds, its durability and the ease with which it may be quarried and dressed, together with its wide distribution, render it most desirable as a building stone. The pillars of the Court House at Springfield are made of this stone, and though scratched and marred, they are still good examples of the power of this stone to withstand the tests of time.

Hannibal Limestone. Outcrops of this rock occur in many places throughout the northeastern and southeastern portions of the area. The stone appears to be a very much hardened

variety of the shales which are found above them. The output from several well established quarries is widely utilized in Springfield, for curbing, heavy flagging and cross-walks. The formation is nowhere very thick. The beds vary from two inches to one foot, averaging four to eight inches in thickness. The upper beds merge insensibly into the softer shales. All of them have a more or less bluish-green cast, and are frequently covered with immense roots and stems of fucoids.

Gilmore Quarry. This opening is located at the Gilmore mill, on the east bank of the Finley river (Tp. 27 N., R. XXII W., Sec. 36 Ne. qr.). Under a few feet of Chouteau rock are ten feet of this thin-bedded limestone. The output, which is used for heavy flagging and curbing, is hauled by teams to Springfield.

Holman Quarry is situated six miles northeast of Springfield (Tp. 30 N., R. XXI W., Sec. 23 Ne. qr. of Nw. qr.), in the bed of the river. The face has a thickness of about 20 feet, and the layers are easily worked. The rock is mottled, rather shaly, and irregular, having a greenish coating on a bluish ground, and the slabs are extensively used in Springfield for sidewalks, curbing and crossings. This quarry was opened in 1889, and has been worked almost continuously. It has six workable ledges, varying in thickness from four to six inches. The ledges now exposed cover about two acres. It has a wide use, in the city of Springfield, and especially in St. Louis, where a considerable amount is sent for curbing. It is supplied in Springfield at the following rates: for curbing, 50 cents a running foot; for flagging, from 25 to 45 cents a square foot. Poorer grades are put down as street crossings at 12 cents a square foot.

The M. H. Southworth Stone Company have recently purchased the Johnson quarry, situated on the south side of the Finley, in Tp. 27, R. XX W., Sec. 15, Ne. ¼ of Ne. ¼. This quarry was opened in the fall of 1890, and is the best bed yet seen in this formation. The rock is fine-grained, compact, hard, and breaks with a splintery, conchoidal fracture. It is in beds varying from three inches to one foot in thickness, and some-

what resembles the Burlington in color and texture. In this quarry are nine curbing ledges, averaging seven inches in thickness, and the stone from these is laid down in Springfield at fifty cents a square foot. One flagging ledge, three inches thick, is placed in Springfield at twenty-five cents a foot. The beds of this quarry have an aggregate thickness of from 10 to 12 feet, underlying 10 inches of Chouteau, the minimum thickness of this last formation in this area.

The Cramer Quarry is located about three miles north of the Southworth quarry, Tp. 27, R. XX, Sec. 11, Se. ¼, about one-half mile from the Finley, and in the Vermicular limestone. It contains about 15 feet of workable ledges, and the owner states that the flagging can be placed in Springfield at a cost of about 18 cents a square foot.

Of the Webster beds, the Sac limestone, where thick enough and free from pyrites, would make a most beautiful stone for architectural purposes. It contains enough silica to make it susceptible of a fair polish, and is but another evidence of the undeveloped resources in which Missouri abounds.

Sac Limestone. Where thick enough and free from pyrites this rock would make a beautiful stone for architectural purposes. It is susceptible of a fair polish.

Silurian Limestones. While widespread and possessing all the advantages of the dolomitic rocks as regards fineness of structure, beauty and great durability, these rocks have been almost wholly neglected. Except in the extreme southeastern portion of the district, the beds of the First Magnesian layers are worthless for building purposes, being too silicious and irregularly bedded to render it ever possible to utilize them.

The middle beds of the Second Magnesian, however, frequently possess all the qualifications requisite for a good quarry rock. It is the compact, fine-grained, white, and heavily bedded stone, called "cotton-rock," and while soft when first quarried, hardens with time and exposure.

One of the handsomest building stones in all the territory is a beautiful dolomitic limestone, obtained from a small quarry in the Third Magnesian, which is located three miles northeast

of Fair Grove (Tp. 31 N., R. XX W., Sec. 15), on the south side of the Pomme de Terre river. On the Adams place a large two-story house was constructed entirely from stone obtained in this quarry. It is a beautiful white, compact, fine-grained rock of homogeneous texture, and at a little distance resembles marble.

The remarkable durability of the dolomitic rocks is well exhibited in the tombstones in the old cemetry in the M. E. church-yard, in the southeastern corner of Polk county, and four miles northwest of Fair Grove (Tp. 41 N., R. XXI W., Sec. 12). A number of the stones date back to 1840, and the inscriptions are as legible to-day as when first carved. Time and weather have served only to harden the stones.

ORNAMENTAL STONES.

Aside from certain of the layers of the stones already mentioned that are susceptible of taking a high polish, and that are adapted to other purposes than the rough constructional uses to which they are now put, there is the onyx or cave marble. It is chiefly a stalagmitic formation occurring in caverns. There are large deposits in the caves of the district, and especially in Christian county, but the stone often contains flaws and such other irregularities as would make it unfit for ornamental purposes. It is possible that when these deposits are more fully explored, more compact masses may be found. Some samples on exhibition at the Springfield mining bureau are very handsome, and were they perfect, would equal the so-called Mexican onyx in richness of coloring and marking. The development of these beds would doubtless lead to the establishment of a profitable industry.

LIME.

The manufacture of lime is fast becoming a large and important industry in Missouri, the state ranking seventh in the United States in 1889, when the value of the production was nearly $400,000, the product of Greene county exceeding that of any other county in the state. Up to 1867, all the lime

manufactured in southern Missouri was prepared in the rudest manner. Log heaps were built, and rough blocks of limestone were thrown upon them to be burned in the simplest way, or rough stone walls sufficient to support and retain the rock were built, and the lime was burned in these temporary kilns. Such structures as these are scattered throughout the county, notably at the following points: on the bluff at the Pierson creek mines, near the Ingram mill; at the ford north of Doling park, Springfield; east of Ebenezer and at the Patterson place north of the Public square, in Springfield, near the present intersection of Water and Boonville streets.

The first introduction of modern methods of manufacture was by the Ash Grove White Lime Association. The company now largely controls the trade of the southwest, shipping to Kansas, Texas, Colorado, and even to the Pacific coast. A history of this company is essentially a history of the development of the lime industry in southwestern Missouri.

From a commercial stand-point, the manufacture of lime in southwestern Missouri was started at Peirce City, in 1872, by J. H. Barton, who is now secretary and manager of the Ash Grove White Lime Association. He built one kiln at this point. The pioneer industry had all the business that it could do, the product being shipped to all points on the St. Louis and San Francisco railroad, even as far as Texas. The rock used for the manufacture of lime at this and all points in southwestern Missouri is obtained from the Upper Burlington limestone, mainly the middle beds, which are very pure, and which burn into a superior quality of white lime. In 1887, Mr. Barton sold his kiln to C. A. Raupp, who added one kiln, and has thus conducted the business up to the present time, 1896. In 1884, at the beginning of the rapid development of this part of Missouri, the demand for lime exceeded the supply, and the business became so profitable that a number of new companies were organized. J. Wilson and P. J. Lehnhard built another plant at Peirce City, and later added a second kiln, which was operated for several years. It was eventually sold to Mr. Raupp, who now runs all four kilns. These were the first

modern continuous draught kilns erected in the southwestern part of the state. In 1878 Charles Hubb and W. B. Hill built two kilns at Carthage, and organized the "White Star Lime Works." Later, a Mr. Garner built two kilns at this place, and operated them in connection with a stone quarry, which was the first introduction of the dimension stone business in southwest Missouri. The Garner company soon ceased to make lime, and confined its business to shipping sawed blocks of limestone. In 1883, W. B. Meyers built two kilns at Carthage, which are still in operation.

In 1880, the late Gen. G. H. Nettleton, general manager of the Kansas City, Fort Scott and Gulf railroad, called the attention of Mr. Barton to the large amount and fine quality of limestone thrown out of the deep cut of the railroad west of Ash Grove, and urged the importance of establishing a lime plant on the line of this road. A car load of the stone was shipped to the old Burns kiln, at Springfield, and burned into a fine quality of white lime. Mr. Barton immediately erected two kilns at Ash Grove, and the following year, W. B. Hill, of Carthage, became associated with him. Two years later Barton and Hill organized a stock company, known as the Ash Grove White Lime Association, which now runs nine kilns. During the past winter the stacks of these kilns have been raised sixteen feet, giving them a total height of eighty-two feet. The old round, monitor kilns have been modified into square iron kilns. The increased elevation of the stack adds materially to the output without increasing the amount of fuel consumed. The largest stack holds about 600 bushels of lime, and lasts from six to eight months without patching. The company consumes thirty-six cords of wood a day when running full blast, with a maximum product of 900 barrels of lime. The average output is 700 barrels per day. Twenty-five men are employed at the kilns and twenty-three in the barrel factory. In 1886, the same company built two kilns at Everton, which were soon increased to four, and it also operates two kilns at Galloway.

In 1884, Messrs. Armstrong and Watts erected a kiln at Galloway, but the business proving unsuccessful, it was finally abandoned.

About 1881, P. Mugan built a kiln outside of the city limits of Springfield, near the old St. Louis road. This was operated for several years, when he associated himself with C. R. Hunt, and built two kilns at Phœnix. This company shipped a considerable amount of lime, and Mr. Mugan then sold his interest to the Phœnix Stone and Lime company, by which the kilns are still operated in connection with the dimension stone quarry. The following is an analysis of this lime, made by R. R. Hunter, of Kansas City:

	Per cent.
Lime	88.50
Magnesian	.343
Alumina	10.100
Iron oxide	Trace.
Undetermined and loss	1.057
Tolal	100.000

About ten years ago Hauck and Thomas, of Wichita, Kansas, built two kilns at Sarcoxie, operating them successfully for several years, and then selling them to the Marblehead Lime company of Chicago, which has recently bought out the Springfield White Lime works. About the same time that these kilns were started, Hinckley, Hedges and Co., bought a tract of land at South Greenfield, erected two kilns, and also opened a dimension stone plant. These kilns were afterwards leased to the Ash Grove White Lime Association, and have not been run for the last two years.

In 1884, Mr. James H. Smith built a kiln at the junction of the St. Louis and San Francisco and the Kansas City, Fort Scott and Memphis railroads, in Springfield, and sold a one-half interest to J. G. Schermerhorn. Another kiln was soon added, when Mr. J. S. Atkinson purchased an interest, and the Springfield White Lime association was organized. One kiln was added in 1885 and another in 1886. In 1894, this company sold out to the Marbehead company, of Chicago, which continue the operation of the plant with the addition of two new kilns.

The Burns kiln is east of the Springfield White Lime plant. It was started in 1875, and was operated until 1890. Up to 1884, one kiln supplied all the demand for lime in Springfield and vicinity.

The Mugan kiln, located at Walnut Grove, and is still operated.

The Smallwood kiln is on the Clinton branch of the Kansas City, Fort Scott and Memphis railroad, near Osceola, but is not now in operation.

The following table gives an approximate estimate of the yearly output of the principal plants:

	Bbls.
Ash Grove	130,000
Springfield	72,000
Everton	48,000
Peirce City	40,000
Phœnix	40,000
Carthage	30,000
Galloway	24,000
South Greenfield	18,000
Sarcoxie	14,000
Walnut Grove	6,000

One barrel equals two and one-half bushels of lime. The price of lime has been greatly reduced in the past few years by competition and by improved methods of manufacture. In Springfield, in 1884, it sold for 80 cents a barrel, while in 1896 it brought 55 cents. The average price in southwest Missouri, for the lime alone is about 37½ cents, the cost of the barrel varying in different localities. Fuel varies greatly in price. At Springfield the average cost is $2.25 a cord; at Ash Grove, $1.75; at Galloway, $1.65. It takes about two cords of wood to make one hundred bushels of lime. Two things are necessary in burning lime; first, intense heat; and second, a bright, far-reaching flame that will pass up the kiln and circulate through the broken rock. To produce the requirements, experience has shown that black oak is, by far, the best fuel, well seasoned elm ranking next, hickory being very poor and post-oak poorest of all. Coal may be used, but it does not make a white lime. The life of a well-constructed kiln is about one

year. No fire brick has been found that will stand the intense heat of the kiln. The surface presented to the flame constantly cracks off, fluxes with the pure lime and runs off as glass. Experience has not yet demonstrated the proper height for the kilns. Increasing the height of the stack gives greater draught, more heat, and enables a larger amount of lime to be burned; on the other hand, the kiln burns out more rapidly, and the matter resolves itself into the question as to whether it is better to have a larger amount of lime at the expense of the kiln, or have a smaller amount of lime with longer service from the kiln. The experiment of the Ash Grove White Lime Association in increasing the height of the stack will be watched with a great deal of interest. The territory into which manufactured lime in southwestern Missouri is sent includes the following states: Missouri, Iowa, Nebraska, Kansas, Colorado, Wyoming, New Mexico, Indian Territory, Arkansas, Texas and Louisiana.

ROAD MATERIAL.

Material for macadamizing roads is readily obtainable throughout the district. The limestone and chert from the Upper Burlington limestone has, heretofore, been mainly used for this purpose, as seen in the Government boulevard between the National cemetry and the city of Springfield, and on Boonville and St. Louis streets in the same place. A great mistake has been made in using this material, as it is so soft that it rapidly pulverizes, and forms an impalpable dust that is very disagreeable in dry weather, and the roads are also quickly cut through by heavy teaming. The use of the hard Lower Burlington limestone and chert is strongly recommended where macadamizing is to be done. The splendid natural ridge roads on the Lower Burlington in Christian and Stone counties testify to the superior qualities of the limestone and chert of this formation for road-making purposes.

Cementing Gravel. Two years ago a fine deposit of a water-worn gravel, mixed with a certain proportion of cementing clay was found just west of the switch at Gates station, on the

Chadwich branch of the St. Louis and San Francisco railroad, Tp. 28, R. XXI, Sec. 20, Sw. ¼. This is probably a Tertiary deposit, and is situated at an altitude of about 40 feet above the James river, and about a quarter of a mile away from that stream. The bed has been exposed for about a quarter of a mile along the right of way of the railroad, and the road running south from Gates indicates its extension for nearly half a mile to the southeast. There seems to be an inexhaustible supply of this gravel, which experiment has proved to be the best and cheapest macadamizing material accessible to the city of Springfield.

COAL.

Greene county lies just beyond the limits of the great Western Interior coal field. The nearest deposits of coal which are being worked at the present time are situated in Dade county, not far from the Greene county limits. With such close proximity to workable deposits, it would be expected that outliers of the Coal Measures, and even workable pockets of coal should occur. This is, in fact, the case. Although in several localities coal is known to exist, it is only in one that it is pure enough to be of value. This is on the Kincaid farm, about one and one-half miles southeast of Brookline (Tp. 28 N., R. XXIII W., Sec. 10, Sw. qr.). This deposit is situated in a much tilted ridge of sandstone. A shaft sunk to the depth of 110 feet, gave the following section:

Section of Kincaid Shaft.

		Feet.
8.	Shale and sandstone	68
7.	Shale, dark, with few fossils	8
6.	Coal	2¼
5.	Shale, light colored	12
4.	Coal	2½
3.	Shale, black, with fossils	6
2.	Rock, Silico calcareous "knotted"	12
1.	Coal, covered by a thin layer of shale (exposed)	1

The seams of coal are greatly inclined, having a pitch in places of 45 degrees N. by W. But little drifting has been done. Although the coal of the middle and lower veins is quite pure, making an excellent grate coal, little investigation

has been made regarding the extent of the beds. Prospecting with the drill would demonstrate the extent of the deposit, which, if large enough to justify working, would have additional value, because of its nearness to the railroad and to the city of Springfield.

In 1860, a vein of less than two feet of impure coal was discovered in two shafts, one-half mile southeast of the Kincaid place, on the Moore farm, Tp. 28, R. XXIII W., Sec. 15, Ne. ¼ of Ne. ¼. It is near the southern limit of the sandstone belt, and the carbonaceous shale is still seen on the old dumps. The top of these shafts is about 50 feet below that of the Kincaid shaft. A well sunk about one-half mile east passed through 137 feet of Upper Burlington limestone, demonstrating the abrupt limits of the coal area in that direction.

At Campbell station, on the Kansas City, Ft. Scott and Memphis railroad, is a coal pocket which covers several acres. It was discovered in digging a well, which is 49 feet deep. In this well, under ten feet of slate and shale, very thin seams of coal are found, alternating with shale and gray bituminous limerock until bottom is reached. The deposit is too impure to be utilized.

CLAYS.

One of the most promising of the future industries of this region is the development of the fine bodies of clay and clay-shales of various grades found within the limits of the area. These clays, unlike the purer kaolins which are associated with the granitic rocks, are all secondary residual deposits from the denudation, decomposition and segregation of different formations, but they are mainly derived from the Coal Measures, having been, originally, the cementing material of the sandstones, and probably, to a degree, of the limestones.

Chemical composition is of great importance in the utilization of clay, which may be separated into its proximate constituents, such as kaolin (the hydrous silicate of alumina) or clay proper, water, sand, mica, lignite, pyrites, and salts of lime and potash. All but the kaolin is impurity, and may be absent

or present in varying proportions. The quantitative analyses of these clays has been given in the special report on this subject recently issued from the office of the Survey, by Prof. H. A. Wheeler, of St. Louis, Mo.

The foreign ingredients of clays will now be briefly considered, as determining the value of the deposits of this area, in order to facilitate the intelligent discussion of these deposits.

First, water. This is present in all clays, chemically or physically combined, giving the important physical property of plasticity, although it is, probably, not the only cause of plasticity.

Second, quartz. This is always present, and varies greatly in amount, ranging from one-fifth of one per cent. to as high as sixty per cent., averaging about five per cent. in the best fire-clays.

Third, mica. This exists in minute scales or flakes, and is mainly confined to thin layers in the Coal Measures clays, though not always found in them. The presence of mica is quite detrimental, since it contains sodium and potassium, salts which render the clay more fusible, and useless for fire brick.

Fourth, iron. This is almost a universal constituent, and forms the coloring matter of clays, their variegated colors being due to different proportions of iron. If three per cent. or more is present, the clay loses its refractoriness, and cannot be used for fire brick.

Fifth, lignite. This is fossil vegetable material, and is rarely, if ever, present in clay below the Coal Measures. In moderate amounts it is not injurious, and, in some cases, rather facilitates burning, rendering the product somewhat lighter colored.

Sixth, pyrites. This is not a common impurity. When present, it is usually in small rounded masses, "sulphur balls," and these are usually in certain levels of the deposits. It is a comparatively easy matter to separate them from the other levels. If present in minute particles, and generally distributed

through the bed, the clay, if otherwise valuable, i. e., rich in silicate of alumina, may be utilized in the manufacture of alum. The presence of pyrites is very deleterious, as it promotes, to a high degree, the fusibility of all clays in which it is found.

Seventh, limestone. This is an impurity which, in burning, is changed to calcium oxide, or quick lime, and this, absorbing water, would cause the clay to slack. Many clays could be improved by washing and mixing with other clays having desirable characteristics.

The important physical characteristics of clay are plasticity, density and fusibility. The first is a fundamental quality, the power to absorb water, which renders it easily molded into any desirable shape. When dry it hardens, and becomes like stone when baked, and the plasticity can never be restored.

Density is important in its relation to the various uses to which clay may be put, the denser varieties being more valuable for fire-brick and household utensils.

The relation of various impurities to the fusibility of clays has already been briefly mentioned.

The clay deposits of Greene county are mainly confined to three formations, the Coal Measures, the Upper Burlington and the Hannibal. The clays of the Coal Measures are, by far, the purest and best of all. They are mainly confined to the townships on the western border of the area. Only one deposit has, as yet, been developed, that at Billings, the following account of which is taken from Professor Wheeler's excellent description in "Clay Deposits," Missouri Geological Survey, Vol. XI, p. 374: "One mile southeast of the railroad station at Billings, a soft, dark, drab shale has been opened in a shallow pit near the crest of a gentle hill where over 10 feet are exposed. It pitches at an angle of about 50 degrees to the east, and is overlain by a coarse, brown to red sandstone that is over three feet in thickness. This shale has been used to a limited extent at the Billings pottery for terra cotta, with decided success, as it burned to an attractive buff color, and makes a strong ware. Two and one-half miles southwest of Billings, at the former site of the Updegraff brickyard, another bank of

shale has been opened on the north side of the St. Louis and San Francisco railroad. The shale is below the general level of the prairie in which it occurs, and is worked by a pit that is below water level, so that constant pumping is necessary. Two pits have been opened to the underlying shale, the largest one being about 150 by 125 and over 30 feet deep, while the smaller one is about 50 by 40 feet. There is a stripping of soil from 2 to 3 feet, below which is a sandstone that on the eastern face of the large pit has a thickness of 3 feet, and a local dip of about 15 degrees to the south, while on the northern face the shale dips about 25 degrees to the east. The probable thickness of the shale at this point is at least 20 feet, and likely more."

The following is a section obtained at this point:

		Feet.
4.	Soil	1
3.	Conglomerate	3
2.	White clay	45
1.	White sand	3

Continuing the description, Mr. Wheeler says: "A sample that was collected gave the following characteristics: Color, very light gray, with abundant stainings of iron. Texture, somewhat coarsely lamellar, rather soft, fine-grained, and uniform. Taste, very smooth, and slightly of alum. Slacked readily and completely to granules and flakes of one-fourth to one-fiftieth of an inch in size. Pyrite was not noticeable, mica was present in small white scales. When ground to 20-mesh it made a plastic paste with 23.0 per cent. of water, which shrank to 7.3 per cent. in drying and 6.7 per cent. when vitrified, giving a total shrinkage at 14.0 per cent. The dry mud had an average tensile strength of 98, and a maximum of 109 pounds to the square inch. Incipient vitrification occurred at 2,000 deg. F., complete at 2,200 deg., and viscous above 2,400 deg. The clay rapidly dried without cracking, but needed to be slowly heated to avoid checking. It burned to a pale buff color, and made an excellent quality of terra cotta, for which purpose it was used at the Keightly Manufacturing Co., at Billings. A chemical analysis of the shale gave the following results:"

	Per cent.
Silica	63.11
Alumina	23 11
Combined water	7.05
Sesquioxide of iron	1.79
Lime	0.42
Magnesia	0.70
Alkalies	3.71
Total	99.89
Total fluxing impurities	6.62
Specific gravity	2 16

Some Springfield parties organized the Springfield Fire and Paving Brick Co., at Billings, and equipped their plant with a No. 7 Penfield stiff-mud machine, with a 40-horse power engine and boiler. Three clamp kilns had a capacity of 150,000, but yielded only a small percentage of the best pavers, the main output being building brick which found a market in Springfield. The business of this company was not successful, and was discontinued in 1892.

The Kelso clay beds are, next to the Billings deposit, probably the most promising of any yet discovered in the area. They are situated about four miles west of Willard, in Tp. 30, R. XXIII W., Sec. 20, Ne. qr. of Sw. qr. Several prospect shafts have been sunk, and evidence of a large and valuable deposit found. One shaft, at a depth of 30 feet, passed through the following strata:

Section at the Kelso Shaft.

		Feet.
6	Soil, red clay, with imbedded clay nodules	2
5.	Limestone, with chert, dark colored, coarse	5
4.	Shale, variegated, reddish and greenish	3
3.	Shale, compact, bluish with occasional thin seams containing fossil plants	18
2.	Shale, black, with crystals of selenite	4
1.	Shale, black	3

The surrounding rock is a coarse bowlder conglomerate. The upper portion of the clay varies from greenish to reddish, but the great mass of the bed closely resembles, both in plasticity and chemical composition, the Billings deposit. Its freedom from mica and iron makes it a most promising variety for the manufacture of fire-brick and all kinds of pottery. The nodules of clay mentioned in the first two feet of the section

are the mineral Halloysite seem to be peculiar to this area, at least they have never been seen at any other point. They vary from the size of a nutmeg to masses several inches across. They are imbedded in an impure, ferruginous clay, resembling the Upper Burlington clay soon to be described, and when freshly broken, are delicately and beautifully colored from a rich salmon color through the various shades of red, pink, yellow, blue and green. These nodular masses seem to have almost completely lost their plasticity, and they are hard and brittle. It might be supposed that they are masses of the clay that have been baked by surface fires, but the finding of them at greater depths in other shafts precludes this idea. The proximity of this deposit to the railroad, the purity of the clay and the size of the deposit, as indicated by the prospect holes, are all facts in favor of its further development. The clay in the ochre beds on the Long farm (Tp. 30 N., R. XXIII W., Sec. 21), a short distance south of the Kelso locality has already been noticed. The fifteen feet of clay found just above the ochre deposit is the purest and the finest quality of clay that has been noticed in the southwest. It is pure white, free from grit and very plastic. If the area of the bed is sufficiently large, as is indicated, this will prove even more valuable than the ochre.

A little over a mile to the southeast on the south slope of a draw running into Clear creek (Tp. 30 N., R. XXIII W., Sec. 32, Ne. ¼ of Se. ¼), a shallow prospect shaft has been sunk on the Lintner farm, showing conditions similar to those on the Kelso land. The red, ferruginous clay filled with nodules variegated in color was found, but the excavation was not deep enough to indicate the nature of the deposit below.

On the Gilmore farm, three miles northwest of the Kelso beds, deposits similar to those at Kelso's have been found.

Information has been received of similar beds near the Evans mill, fifteen miles northwest of Springfield, and also east of Cave Spring, on the Sac river. It is stated that a large and valuable deposit of clay has just been discovered two and one-half miles northeast of Buckley. From data already obtained,

there is little doubt that other and equally valuable clay-beds will be found in the future in this territory.

G. A. Ramsey, of Springfield, exposed a bed of clay eight feet in thickness in sinking a well, situated near the head of a valley that extends up from the McCracken mill on the Sac (Tp. 29 N., R. XXI W., Sec. 5, W. ½ of lot 4, Nw. ¼). The well is 18 feet deep and is in a small area of Graydon sandstone lying in an Upper Burlington valley. The bed is evidently a local pocket. In appearance and plasticity it is similar to the Kelso deposit, and some fine samples of brick and pottery have been made from it.

On the McAdams farm, northeast of the McCracken mill, a small bed of clay somewhat similar to that encountered in the Ramsey well was also found. Also on the Childers land (Tp. 28 N., R. XXII W., Sec. 16, Sw. ¼ of Nw. ¼), clay and shale were struck in a well 29 feet deep.

The clays derived from the Upper Burlington limestone, as has been stated, are highly ferruginous, very impure, and mainly utilized in brickmaking. The residual material is called geest, and is mainly formed from the breaking down of the upper shaly and cherty beds of the Burlington formation, and in places partially derived from the sandstone that overlaid the formation. These deposits are very large, scattered over the whole area, and are practically inexhaustible. Wherever subterranean drainage has been imperfect, the low, flat, swampy tracts are found, in most cases, to be underlaid by deposits of this clay. But few of the numerous and widely scattered beds have been worked.

The Rand brickyard is one of the most prominent, and the largest yard which has supplied brick for the city of Springfield. It furnishes the raw material for the brickyard in the western part of the city. This clay covers an area of about thirty acres. It is about eight feet deep, and requires, practically, no stripping. The deposit has been worked since 1881. During the season of brick-making, from 25 to 30 men are employed, and the total output has been about 25,000,000 bricks, with an average annual production of about 1,200,000.

A considerable amount of this product is transported to southeast Missouri. The wholesale price at the yards is five dollars a thousand, or six dollars delivered in the city of Springfield. The poorly drained land west of Springfield along the St. Louis and San Francisco railroad contains a practically inexhaustible amount of clay. In this locality the McCain brickyard was in operation for several years. It was only worked a portion of the time, with an output of 400,000 brick, and it has since been incorporated with the Rand yard.

East of Springfield, on the McClure land, a small bed has been worked for a number of years, with an annual output of about 300,000 brick; and north of the fair grounds, in the same city, is another well-established plant, the Quick brickyard, with an output in 1893 of about 1,000,000 brick.

Southwest of the city, near the Kirchgraber place, on the Mount Vernon road, Geer, Loyd & Co., have recently opened a new yard. The annual product is about 1,000,000 brick.

At Ash Grove, the Walker yard has been worked since 1886. The total output is about 4,000,000 brick, that of 1895 being about 400,000. The clay-bed is located at the juncture of the main line and the Clinton branch of the Kansas City, Ft. Scott and Memphis railroad. The deposit covers about ten acres, varies from two to four feet in thickness, and requires no stripping. During the season, from April to November, the yard employs from 20 to 25 men. The product of this yard is mainly used in buildings, flues and sidewalks in Ash Grove and the surrounding country. The retail price is 80 cents a hundred, and the wholesale $7.50 a thousand.

The Britain yard at Republic is west of the town. It was opened in 1892, and has produced about 1,800,000 brick. The output for 1895 was 500,000. This is a small tract of land, of about two acres, and the clay is from three to four and one-half feet thick. During the working season 15 men are employed. The product brings from $5.50 to $6.00 a thousand wholesale, and 80 cents a hundred retail.

At the Julian yard, at Walnut Grove, 200,000 brick were manufactured in 1895. The yard is located near the railway station.

The clays of the Hannibal sandstones and shales have not, as yet, been utilized within the limits of this district, though north of Bolivar, in Polk county, a thriving plant using the material from this formation was established years ago. There is no reason why the heavy and wide spread deposits of this horizon in the north-half of the district should not be utilized for the cheaper grade of products.

So far as can be learned, no deposits of workable clay from any other formations exist within the limits of this territory.

MOULDING SAND.

In several localities fine beds of moulding sand has been found in the Upper Coal Measures. That on the Hibler farm and the adjoining Kincaid tract next to the railroad, in Tp. 28, R. XXIII W., Sec. 10, Sw. ¼, has been largely used by the Springfield Stove works.

IRON.

No workable beds of iron ore, so far as present knowledge extends, exist within the limits of the area. The sandstones of the Carboniferous frequently contain nodular masses of limonite. Withstanding the destructive power of atmospheric and aqueous agencies better than the matrix, these are left with the residual material, while the softer, lighter and the more easily decomposable material is carried away. At a number of points such surface deposits are large enough to delude the prospector with the idea that they are outcroppings of heavier beds below. Such a deposit is found near the Kelso clay bed (Tp. 30 N., R. XXIII W., Sec. 20, Sw. qr.). Swallow * has given the following list of localities for iron ore in the form of hematite in the area:

Tp. 30 N., R. XX W., Sec. 26, hematite.
Tp. 27 N., R. XXIII, Sec. 19, W. hf., hematite.
Tp. 27 N., R. XXIII W., Sec. 7, Sw. qr,, hematite.
Tp. 28 N., R. XXIII W., Sec. 4, Nw. qr., hematite.
Tp. 28 N., R. XXIII W., Sec. 4, Sw. qr., hematite.

* Geological Report on the Southwestern Branch of the Pacific Railroad, G. C. Swallow, 1859, p. 35.

Tp. 28 N., R. XXIII W., Sec. 5, hematite.
Tp. 28 N., R. XXIII, Sec. 8, Nw. qr., hematite.
Tp. 28 N., R. XXIII, Sec. 9, Nw. qr., hematite.
Tp. 30 N., R. XXIII, Sec. 5, Ne. qr., hematite.
Tp. 30, R. XXIV W., Sec. 19, oxide.
Tp. 29, R. XXIV W., Sec. 4, oxide.
Tp. 29, R. XXIV W., Secs. 24 and 25, brown hematite.
Tp. 30, R. XIX W., Sec. 18, oxide.
Tp. 27, R. XXIV W., Secs. 14 and 15, hematite.
Tp. 27, R. XXIV W., Sec. 23, hematite.
Tp. 27, R. XXIV W., Sec. 24, E. hf., brown hematite.
Tp. 28, R. XXIV W., Sec. 1, hematite.
Tp. 29, R. XXIV W., Sec. 12, hematite.

These, as well as other localities observed, are merely residual deposits of ore from the coal measure sandstones. Professor Broadhead states that "near the line between Webster and Greene counties (Tp. 30 N., R. XIX W., Sec. 18), hematite is found in fragments, some of them quite large. They occurred in a ravine about the line between the saccharoidal sandstone and the second magnesian limestone." A recent visit to this locality resulted in the finding of only a few residual masses of limonite left by the breaking down of the sandstones. There is no evidence, whatever, of any paying deposit of iron. It is further stated by the same authority, that large masses of fibrous brown hematite are found in the southwest quarter of section 19, township 27 north, range 23 west. The same excellent ore covers many acres in the northwest quarter of the same section. It also abounds in section 7 of the same township. Both small and large nodular masses of limonite, and sometimes hematite, ores are found scattered over both the coal measure sandstone deposits and in their immediate vicinity on the Upper Burlington limestone, where they have been left by denudation. Many samples may be found in the stone walls and fence corners on Grand prairie. In 1885 several shafts were sunk on the Hill farm, on the conglomerate ridge, south of Bucksnort Hollow (Tp. 29 N., R. XIX W., Sec. 5, Ne. qr., lot 7). A small local deposit of bog-iron ore was discovered. It was evidently residual from the conglomerate. Sometimes the iron ore is found as residual material filling crevices, as, for example on the Wilson farm (Tp. 30 N., R. XXIII W., Sec. 32, Nw. qr.). The vein which was traced for a distance of

twenty feet, was two and one-half feet wide, and about twenty feet deep. The crevice walls were of sandstone. The drill penetrated nineteen feet further, in calcite and iron. The ore was a good quality of limonite.

The iron in the residual clay covering the upper beds of the Upper Burlington, frequently approaches bog-iron ore in composition. In the quarry near the old cotton mill in the city of Springfield, such a deposit was found filling a "flat opening" where the underground drainage had segregated it. The bed had a thickness of about two feet.

In a number of places in the Coal Measures sandstone deposits, in the western part of the area, the residual material from denudation of the sandstone has been so great as to form large deposits of excellent yellow ochre. On the Long farm a fine bed of this ochre was discovered in 1887 (Tp. 30 N., R. XXIII W., Sec. 31, Ne. qr.). In 1892 it was leased to the Bois d'Arc Mining company, and worked for a short time. Altogether six shafts with drifts were sunk on the tract, and in the deepest shaft which reached a depth of 70 feet, 35 feet of ochre was exposed, under 15 feet of a fine white clay. The material requires washing, and the ochre is, apparently, of a very good quality. The Bois d'Arc company discovered another deposit, in Tp. 30, R. XXIII, Sec. 31, Se. ¼, where, in the fall of 1891, a mill was erected. It is the intention to work both deposits. Undoubtedly other excellent beds of ochre occur in the same township.

WATER AND WATER POWERS.

Next to an equable climate and pure air, the possession for which southwestern Missouri is most grateful, is her abundant supply of cold and sparkling waters, which, for the most part, come to the surface in large springs generously scattered throughout the whole district.

SURFACE WATER SUPPLY.

The surface waters of the area are exceptionally pure. All have their origin in large springs, so that even in the most protracted drought they are never-failing. Few parts of the

country are better watered or possess better facilities for the utilization of water-power than southern Missouri, particularly that part of the state under discussion in this report. The growing demand for water-power, due to the progress in electrical science, greatly enhances the importance of a proper knowledge of our water-supply. The James and Finley rivers, and Wilson creek, with their spring branch tributaries in the southern half of the area, and the various branches of the Sac and Pomme de Terre rivers with their tributaries on the north, afford numerous mill sites with practically inexhaustible reservoirs, which but await the needs of advancing civilization. The Greene County Game and Fish Propagating Club have made careful investigations concerning the temperature and purity of these waters, with a view to restocking the streams with the finest varieties of game and food-fish. The temperature of the various springs, in the hottest weather, runs from 44 to 58 degrees F., and of the streams from 60 to 67 degrees. The extent and character of the water-supply of this area can be better appreciated after a brief consideration of some of the principal springs which gush forth on all sides to form the surface streams.

SPRINGS.

The region is truly a country of springs, and there are few areas which have such an abundance of fine, pure, cold water as abound in this portion of the state. The majority of the farms possess one or more of these adjuncts to health and comfort. As Minnesota has been called the land of lakes, so southwest Missouri might be called the land of springs.

The springs of the different horizons vary somewhat in their characteristics, and, while it would be impossible to mention, in particular, each one, there are many that should have brief notice. As might be expected, they usually issue from between two geological formation and their size, purity and temperature depend largely on the horizon in which they have their source. It will be the present purpose to briefly treat of the more characteristic and important representatives of each formation, confining the remarks to such as are not, properly

speaking, mineral springs. The latter will be left for consideration in another place.

The largest and finest springs are located at or near the base of the Upper Burlington limestone. The porous, cavernous nature of this rock, together with its great uniformity and thickness, and the hard Lower Burlington forming a compact under layer, present the most favorable conditions for the accumulation, filtration and distribution of surface waters. Spread out over the western flank of the Ozark uplift, fissured by flexing, and cut into by erosion from the drainage systems, it would be natural to expect large and fine springs along the lower slopes.

The sink holes so abundant in the upper beds of the Upper Burlington form, undoubtedly, great reservoirs for the accumulation of surface waters which are carried by underground channels to, or near the impervious Lower Burlington below. This fact is sufficient to explain the existence of the largest and coldest springs near the base of the upper division of the Burlington. In sinking wells in this formation, water is almost invariably obtained at shallow depths, and large underground streams are frequently tapped which give conclusive evidence of the cavernous nature of the limestone, and the sources of supply of the great springs. It has always been a difficult problem to account for the steady supply of water furnished by the great springs which encircle the base of this formation on either side of the uplift. But this question is now solved by the knowledge that the whole formation forms one vast cavernous reservoir into which the numerous sink-holes and porous strata convey to the underground recesses the surface drainage of the area occupied by this formation. Surprise is frequently expressed at the permanency of the water supply for the numerous large springs that issue from the lower beds of the Upper Burlington on both slopes of the Sprinfield anticline in the near vicinity of Springfield. T. Sterry Hunt has shown, however, that porous rocks may contain an enormous amount of water. He calculated that one square mile of sandstone 100 feet thick will contain water enough to sus-

tain a flow of a cubic foot per minute, for more than thirteen years.

The most important of the immense number of springs issuing from the Upper Burlington may be mentioned. First, and most noteworthy, because of its utilization, is the Fulbright spring, situated near Springfield, in Tp. 29 N., R. XXII W., Sec. 2, Nw. ¼. It emerges from a small cave in a bluff on the west side of the Doling Park branch of the Sac. The Springfield Water Company has built a large stone basin around the spring in order to prevent contamination from the overflow of the creek, that conveys a portion of the sewage from the city three miles distant. The water is wonderfully pure and clear, and has a flow, in ordinary seasons, of 10,000,000 gallons in twenty-four hours, an amount that would be sufficient for a city much larger than Springfield. One mile to the southwest, at the Ritter springs, a large lake has been formed by damming the mouth of the narrow valley into which three great springs empty, making one of the most picturesque points in the vicinity.

Another important spring is the one in Doling Park, the waters from which have been collected into a basin, forming a lake which greatly beautifies this pleasure resort.

The Woolen Mill spring, in the northwestern part of the city of Springfield, the Dingledein spring, in the western part of the same city, at the brewery, the Jones spring, in the eastern part of the city, the Lyman spring, just north of the "Square" on Water street, and the Frisco spring, north of the St. Louis and San Francisco car shops are all fine and large. The site which they encircle was the seat of a large and prosperous Indian village long before the appearance of white men in this region. The last mentioned springs, owing to their situation in a thickly settled region, are all more or less contaminated with sewage, and Jones spring, especially, is unfit for domestic purposes.

Sander spring (Tp. 29 N., R. XXI W., Sec. 5), just south of the McCracken mill on the South Dry Sac, is another

good example of a spring issuing from the base of the Upper Burlington. It flows from the foot of a low bluff into a large basin, and its discharge is probably 8,000,000 gallons in twenty-four hours. A recent attempt to dam this spring has shown that its waters are the chief source of supply for Fulbright spring, a fact which, in dry times, may be very disadvantageous to the water supply of the city of Springfield. The drainage here, both surface and underground, follows the line of the McCracken-Ritter faulting.

Jones spring, situated about a quarter of a mile from Pierson creek, on the Henderson road, in Tp. 29, R. XXI, Sec. 27, Ne. qr., is an Upper Burlington spring, and must not be confounded with one of the same name already described. It and the Sander spring were once considered as a possible source of water supply for the city of Springfield. It issues from a small cave near the base of the hill, and has a discharge of about 8,000,000 gallons of water in twenty four hours. The "Gulf" railroad passes on a high trestle across the ravine at this point. A small dam has been built, and an effort made to convert this locality into a pleasure park. One of the oldest mills of the township was built here, and part of the wall supporting the mill-race, nearly 20 feet high for about 200 feet, is still standing. The porous condition of the limestone is here beautifully exhibited. The wash of the water, which is rich in lime carbonate, has both worn away the rock and re-deposited the material, together with the lime held in the waters, upon the old wall, forming incrustations several inches thick.

The Fisher cave, on the old Fisher farm, has issuing from its mouth a stream of pure cold water six inches deep, and from four to five feet wide.

Among the numerous springs that help to add volume to the James river, that on the Gates farm, Tp. 28 N., R. XXI W., Sec. 20, issues from a high bluff and discharges immediately into the river. At Camp Cora, on the banks of the James, two miles south of Gates Ford, is another cave and spring, which is a favorite resort for fishing and camping parties. This cave-

spring is, undoubtedly, the underground continuation of a spring branch that rises in Tp. 28, R. XXI, center of the west half of Sec. 24, which sinks and comes out again at the remarkable well-spring in the Ne. of Sec. 22, same township and range, on the Samuel's farm. Just north of Mr. Samuel's house is an abrupt sinkhole, about 30 feet in diameter, and about 30 feet deep, at the bottom of which a bold, clear stream of water flows, entering from a cave opening to the east, and as quickly disappearing in a similar opening on the southwest. Artificial steps have been made so that one can easily descend to this stream. Over all, a platform and well-curb have been erected. A few hundred feet distant a well was sunk which taps this stream, and the two points are connected by an underground passage. The stream flows underground for a quarter of a mile, when it again emerges as the beautiful Russel spring, just south of the center of the same section. From here it flows about 400 feet above ground, and again sinks into a cave-opening, after which it probably re-appears in the springs near the center of the west half of Sec. 28, a mile and a half to the southwest. Here it probably flows for nearly a mile above ground to the center of the Sw. ¼ of 29, same township and range, where it disappears for the last time before emerging at Camp Cora. It is probable that this underground stream is also fed by a spring that rises in the northeast corner of Sec. 27, same township and range, flowing about a quarter of a mile due west, and sinking near the center of the north half of the same section.

Blue spring, also called Sander spring, a popular resort for summer pleasure seekers, Tp. 27 N., R. XII W., Sec. 32, has a flow of about 6,000,000 gallons in twenty-four hours.

The course of the underground stream that feeds this spring is very perfectly outlined by a series of sinks and caves trending south 30 degrees east. The furthermost cave on this line of sinks is a large opening into the bluff half a mile from the spring, and between this cave and the spring is a sinkhole 50 feet long by 40 feet wide and 40 feet deep. A strong current of cold air issues from the east end of the cave, and it is

probrbly set in circulation by the movements of the underground current.

The immense system of underground drainage in the limestone is frequently surcharged after heavy rains, in which case the water is often forced to the surface and forms "wet weather" springs. An excellent example of the temporary springs is found in the Lee spring southeast of Ozark, in Christian county, Tp. 27, R. XXI W., Sec. 23, Ne. ¼. When visited after several days of heavy and prolonged rains, a stream is found to issue from the small cave, the estimated run being 15,000,000 gallons in twenty-four hours. It subsides and dries up after a week or two of dry weather. Dug spring, Tp. 27, R. XXIII, Sec. 30. Nw. ¼, on the old "wire" road, in Christian county, is quite noted in that section of country. At this point, Aug. 2nd, 1861, during the War of the Rebellion, quite a skirmish, known as the battle of Dug Spring, took place. The Haseltine spring, Tp. 29, R. XXIII, Sec. 3, forms the headwaters of Clear creek, and has a flow of about 6,000,000 gallons a day. It issues from a large cave filled with tumbled debris. Considerable salt peter has accumulated in the crevices of the rock at the mouth of the cave. The Amphitheater spring, on Sac river, just east of Percy cave, is a small but clear and very cold stream that issues from near the center of a beautiful curved mural bluff which forms a natural amphitheater of considerable size. A quarter of a mile to the east, on the south bank of the Sac, is the Owen spring, issuing from a small cave on the Owen farm, Tp. 30 N., R. XXII W., Sec. 26, Se. ¼. The head of Asher creek has its source in the small Watson spring in the upper beds of the Upper Burlington, on the Asher. The town of Cave Spring is named from the large stream that flows from the cavern and sink within the limits of the village. Just south of this locality might be mentioned the Hale spring, in Sec. 9, and the Nelson spring in Sec. 4, each having about the same value as Cave spring.

Tyrrell spring, Tp. 27, R. XXIV, Sec. 1, Sw. ¼, is pumped to Billings by the St. Louis and San Francisco railroad, where it supplies their tanks and the town with water. It issues from

the foot of a bluff of Upper Burlington limestone, about 40 feet high. About 300 feet to the northeast of this, another fine spring issues from the bluff on the north side of the valley.

Rocky point spring, Tp. 29, R. XXIV, Sec. 5, W. ½, is one of the largest in West Center township, and a popular place of resort.

The Shaking Mound spring, Tp. 29, R. XXIV, Sec. 15, near the middle of the west line of the Nw. ¼, though small, is a spring that has long created considerable interest throughout the region in which it is located, and has been the subject of some comment in the newspapers. Here the water rises from the summit and seeps off all over the low mound, which is 12 feet high, and 50 by 70 feet in dimension. The mound stands in the river bottom, not far from the junction of Pickerel and Pond creeks, and is most remarkable, from the fact, that it shakes all over when walked upon. Poles are easily sunk in it, through the tenacious turf, and down to a distance of six to ten feet, into the black muck that makes up the bulk of the mound. A dense mat of grass and sedges covers the mound and remains green the whole year. Cattle are frequently mired in the bog. This would, undoubtedly, be a good locality in which to search for the remains of extinct animals, such as the mastodon, and it is a rare example in the south, of the peat bog which is not uncommon in the more northern regions.

Of the Lower Burlington limestone springs, several large ones may be noted. One of these, the Big Boiling spring, Tp. 28 N., R. XXI W., Sec. 16, Se. ¼, is probably the largest spring in the area. It flows directly from a flat orifice extending irregularly for nearly one hundred feet along the bank of the river, and it is either an opening of an underground channel of the river, or, what is possible an outlet for some of the large stream-sinks that occur to the east in this township. Although this is the largest spring of the area, and is situated in the Lower Burlington, the water is, undoubtedly, collected in the rocks of the Upper Burlington, and conveyed downward in a crevice which extends into the lower stratum. Several shafts opening into a brecciated ore-body have been sunk on the

plateau just above the spring, and indicate a shattering of the beds at this point. The spring formerly had its outlet from the cave about 800 feet to the northeast. After heavy rains, quite a stream flows from the cave along the surface of the ground to the present outlet of the spring. The deep and remarkable canon immediately north of the cave just referred to, undoubtedly marks a still earlier outlet of this great body of water, and is also a fine example of a valley of recession. A few hundred feet south of the cave-opening are the Cotton Gin or Roaring springs, a group of ten beautiful cold springs, which occupy a small narrow canon. In the hottest weather these springs have a temperature of 44° F.

The Big Boiling and the Cotton Gin springs are all situated on the property occupied by the Winoka Lodge Club, the summer resort of several Springfield families.

A few miles to the north of Winoka Club House, on the east side of the James and just south of Ingram mill, are several small but well known springs of pure cold water known as Ingram springs.

The Spout spring, on the Dillard farm, issues from a small cave in a bluff on the west side of Pierson creek.

The McKerrell spring, at the head of Pierson creek, is one of the largest and most beautiful of all the Burlington springs and was the location of one of the first settlements in Greene county.

A number of springs in the Lower Burlington formation may be noticed, not so much for their size, though they are large, as for the beauty of their surroundings and the purity and coldness of their waters. These are the Little Yosemite springs, Tp. 29 N., R. XX, Sec. 28, Ne. ¼, the Ozark spring on the south side of the Finely, between the town of Ozark and the railway station; the Johnson spring on the Johnson farm a few miles north of Sparta, the Tallman (old Hayden) springs, Tp. 27, R. XX, Sec. 12, E. ½, on the west bank of Petelo creek, which in early days, helped to run a mill and distillery, the Twin springs on Tyrrell creek, Tp. 27, R. XXII, Sec.

2, Nw. ¼, and the Sweet and Wright springs Tp. 30, R. XXI, Sec. 17.

The springs issuing from the Chouteau limestone are not very large but they are usually connected with picturesque scenery and are almost always points showing good geological sections. A few of the more typical ones may be enumerated; the Rathbone spring Tp. 29, R. XXI, Sec. 3, Nw. ¼, the Barnard spring, Tp. 28 N., R. XIX W., Sec. 23, just north of Panther den, the Peacher spring at Henderson, the Linden spring at Linden and the Hunt Mill spring on a branch of the Sac in Tp. 30, R. XXI, Sec. 22. In the last one mentioned there is a fall of about 50 feet in a few hundred yards, which gives a good head for manufacturing purposes.

The springs of the Kinderhook sandstone and shales are very small, frequently mere seepage springs, forming wet clayey slopes. The water is almost invariably impure and unwholesome, due, no doubt to the decomposition of the pyrites contained in the shales. Wells sunk in this formation almost always contain purgative salts, as in the case of one on the Cochran farm (Tp. 31 N., R. XXI W., Sec 6.).

The springs of the Devonian are small, and almost always seepage springs. The water is frequently contaminated from the Hannibal shales above.

The springs the of Silurian limestones are also small and the water is rather warm. Their size is probably due to the fact that these beds are rarely thick enough in this area for any great accumulation of water. Sand spring, just outside of the county, Tp. 31 N., R. XIX W., Sec. 26, is one of the most important of all the springs coming from the Silurian rocks within the limits of the area. The water bubbles up at the side of the road in several pools, and with a sluggish flow, drains off into a shallow draw to the east.

MINERAL WATERS.

There are few mineral springs in this area. Those at Graydon springs near the extreme northwestern corner of the area are the most important. They are situated near the head of a

small valley that opens into the Sac. There are a number of small weak springs that have their sources in the Graydon sandstone at this point.

Twin Springs. These are the best known of the group. One of them has weak sulphur chalybeate waters, and is called the Sulphur springs, while the adjoining one is a chalybeate spring with only a faint trace of sulphur. Although only separated by a thin slab of sandstone, they probably receive their supplies from different sources. The water of both springs is rather warm, 62° F., and is an unusually agreeable chalybeate sulphur water. Although they have only a local reputation, they deserve a much wider recognition for their excellent tonic qualities. The other springs of this group possess similar characters, but vary somewhat in the amounts of mineral constituents.

The examination of the sandstones below the springs indicates clearly the origin of the sulphur and iron in the abundance of the "pyrite balls." The decomposition of the pyrites in the beds through which the percolating waters pass before issuing at the springs, gives rise to the sulphuretted hydrogen and iron carbonate with which the waters are charged.

A small but well-kept hotel was built near the springs about four years ago by Blystone and Rummell. It has proved, however, wholly inadequate to accomodate the number of guests who visit this locality during the summer season.

The springs issuing from the Hannibal shales have already been referred to in the description of that formation. They are all more or less impregnated with mineral matter derived from the decomposition of the shales through which they pass; yet they do not belong to the class of mineral springs proper.

With the exception of two small chalybeate springs, no other true mineral waters are known in this area. One of them is just under the dam at the pond at the Ritter mill (Tp. 29 N., R XXII W., Sec. 4). This can only be utilized at low water, as the stream overflows it at other times; but its waters are strongly impregnated with iron, and its accessibility to Springfield would make it well worth walling up.

Another small chalybeate spring is found at the foot of the ferruginous sandstone bluff in the bed of Pomme de Terre, at its head (Tp. 30 N., R. XX W., Sec. 25, Ne. qr.).

Specifc Springs. An effort has been made to establish, as mineral waters, a number of springs issuing from the Upper Burlington limestone. Such are the Specific springs in Reilly and Heffernan's park, one of the popular resorts in the vicinity of Springfield. These, however, differ in no respect from the other cool and sparkling springs of the neighborhood.

Bethesda Springs. A few miles northwest of Springfield, Tp. 30 N., R. XXII W., Sec. 20, Sw. qr., are several springs which have had a local reputation in the past, and several houses and cabins have been built in the vicinity. They are situated in the lower bed of the Upper Burlington, and, like many others in this region, can hardly be regarded as mineral springs.

MISCELLANEOUS.

COPPER, SILVER AND GOLD.

Before closing this section on the economic products of the area under discussion, it seems wise to speak briefly of copper, silver and gold. The first, copper, has never been found in the district, with the exception of stains of copper carbornate, and copper pyrites which are rarely found in calcite and limestone in minute traces. Swallow, in his geological report on the Southwestern Branch of the Pacific Railroad, 1859, quotes from Broadhead the following localities in Greene county where copper has been found: "On Sec. 19, Nw. of Sw. qr., Tp. 30, R. 24, very small traces of copper were found associated with calc spar, and traversing the lower silicious beds ('Turnback rocks') of the encrinital limestone in about an E. and W. direction. At William Haralson's, on W. half of Sec. 10, Tp. 29, R. 24 W., a pit has been sunk fourteen feet deep through the lower beds of the encrinital limestone. The ore found here is the sulphuret and green carbonate, in a gangue of coarse opaque buff-colored calc spar, adhering to large crystals of white sub-transparent calc spar, the copper

ore more often occupying the line between the two varieties of spar. Some mining has been done here, but no profitable results have, as yet, been derived. This shaft was sunk in the edge of a valley leading into the valley of the Sac river, and about three-fourths of a mile from that stream. Fragments of copper ore have been found at several places along the valley."

There is very little probability that any workable bed of copper ore will be discovered within the limits of this territory.

The "Turnback rocks" and "encrinital" limestone referred to above are the Upper Burlington limestone.

From the earliest settling of the country to the present time, rumors and traditions of old Spanish mines and smelters for silver have been treasured up throughout the whole Southwest, and these stories have been so frequently met with as to justify some statements in regard to the subject. No silver has ever been found in paying quantities in the area, nor is it likely that it ever will be found. All galena carries a greater or less amount of this metal, but, so far, none has been found here which carried enough to justify working for silver. The stories in regard to ancient mines and smelters all point, undoubtedly, not to the work of Spanish miners, but to that of the early settlers of this region who "gophered" for lead ore. Senator S. W. Headley states that, as far back as 1840 or '45, the sons of Mr. Bedell, one of his neighbors, used, periodically, to visit the farm now owned by James H. Cash, in Tp. 31, R. XXI, Sec. 32, Se. ¼, where they dug enough lead to run out the bullets used for hunting. It has constantly been a source of surprise to the writer that people so soon forget the old mining camps which are in their immediate vicinity. In Webster county, where such large tracts have been worked over, and where the surface, for so many acres, is pitted with abandoned shafts, there were numerous cases where people who had lived, for many years, within two miles of these diggings had never heard of them. Others, when their attention was called to the matter, remember that there were such places, but could not locate them. In a new and thinly settled coun-

try, where people are constantly moving, these matters are soon lost sight of, and, when rediscovered, are naturally referred to a more remote period than that to which they really belong.

It has frequently been said that both the Spaniards and Indians left markings upon the rocks by which secret mines could be located. One of these "marks" discovered not long ago proved to be the fragmentary remains of a fossil coral *evactinopora* (probably *quinqueradiata*, Ulrich), that resembled a star in shape, and which the exhibitor preserved with great care, implicitly believing that it was the clue to some unknown deposit of precious metal.

Of late years, the peculiar rocks of the Devonian beds have constantly led the "old miner" into a belief that they carried some of the ores of the precious metals. This had been, apparently, confirmed in many cases from the fact that the Sac limestone carries finely disseminated pyrites, which, when smelted, in a blacksmith's forge, as has been frequently done, gives a metal called, by some, "white metal," and by others "silver"—the real substance being essentially iron. At several points, quite extensive mining has been done in these beds for the supposed silver. Messrs. Johnson and Cook have sunk several shafts near the middle of Tp. 30, R. XX, Sec. 29, one to the depth of 84 feet. They claim to have obtained considerable silver from this locality, although a sample of what they believed to be nearly pure silver, upon assay was found to be nearly pure lead, with hardly a trace of silver. The record kept in these shafts has been of value in determining the thickness of the horizons of that region.

The Deleware Mining company has sunk several shafts in this formation, the Devonian beds, in Tp. 27, R. XXII, Sec. 29, Sw. ¼ of Se. ¼, on the James river. The sections from their shafts, as well as from Mr. Johnson's, have already been given in the chapter on the Devonian. This company smelted a white metal which they believed to be silver, but which was, undoubtedly, iron derived from the pyrites.

No gold has ever been found in this area, and the geological conditions are such that there is little or no probability of its ever being discovered here.

PETROLEUM.

It is frequently asked if petroleum and natural gas may not be found in this region, and numerous attempts have been made to raise funds to carry on the work of sinking wells in search of them; but in the light that geology offers, it can be asserted that all such attempts are useless, certainly so within the limits covered by this report. This is also, generally speaking, true of artesian, or flowing wells. Traces of petroleum have been found at several places within the area, as at the "Oil spring" at Graydon, and in a well on the farm of Mrs. W. H. Childers, in Tp. 28, R. XXII W., Sec. 16, Sw. ¼ of Nw. ¼, but they are mere traces, only a few drops accumulating on the surface of the water over night. The reasons for the assertions respecting petroleum and natural gas, as well as flowing artesian wells, are as follows: an impervious or "cap" rock is essential for the preservation of both gas and petroleum, and there is no such impervious stratum, as will be seen by the description of the rocks of this area. Again, the geological horizons of this territory, as will be seen in the section on Structural Geology, are frequently very much flexed, folded, shattered and deeply fissured, furnishing favorable conditions for the deposit from below, of the lead and zinc soon to be spoken of, while the conditions would be favorable for the escape of any gas or oil that might have accumulated. Thus the very agent that helped to bring up the rich deposits of mineral, is also responsible for the escape of the gas or oil that might have existed. No instance is known throughout our country where lead and zinc are found in the immediate vicinity of gas and oil. The same conditions of fissuring and flexuring, and the fact that this territory lies across the crest of the Ozark uplift, precludes the probability of a flowing or artesian well.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

Springfield, Mo. Latitude 37, 12′. Longitude 93, 18′. Elevation 1,360 feet.

The following chapter on the climatology of Springfield and the surrounding region has been prepared by T. S. Collins, of the United States Weather Bureau. The important bearing of this subject upon many problems involved in dynamical and physiographical geology will make this section a valuable addition to the knowledge obtained concerning the area covered by this report.

CLIMATOLOGY.

There are so many elements which go to make up the climate of any particular place that it is often difficult from statistics published to determine the seasonal changes. One of the most important elements of any climate is its range of temperature; next in importance is its rainfall, and next the amount of sunshine during the year.

The section of country west of the Mississippi river known as the Missouri valley district, which embraces the Dakotas, Nebraska, Iowa, Kansas and Missouri, marks the greatest ranges in temperature of any section of the United States. This is due to the small amount of aqueous vapor in the air which permits rapid evaporation in winter, and a high degree of insolation in summer.

In the Dakotas and Montana the annual ranges in temperature exceed 140 degrees, and an extreme range of 173 degrees has been noted at Poplar river, in the latter state. This great range is largely due to the dryness of the air over those states.

The monthly ranges of temperature in the upper Missouri valley are extreme, 117 degrees being recorded at Fort Benton, Mont., in December, 1880.

The daily ranges of temperature are of far more importance, and exert a more vital influence on human life than do the monthly or yearly ranges, as violent or extreme changes in temperature within a few hours seriously injure vegetable

and animal life and growth. Over the greater part of the Missouri valley and westward to Texas, the daily ranges of temperature vary from 20 to 35 degrees, the highest ranges occurring in the summer months, from May to July, inclusive. In winter a daily range of 20 to 25 degrees is attended by great suffering to humanity, while the same daily range in summer is conducive to a good night's rest.

During the past decade the extreme range of temperature at this place has been 119 degrees, that is, the thermometer reading has been as high as 102 degrees on September 14, 1893, and as low as 17 degrees below zero on January 24, 1894, while the average daily range has been 20 degrees.

The greatest daily range is during the last two winter months, and from March to July, inclusive; also during September and October. The cold wave period extends through January, February and March, and those are the most trying months of the year on invalids.

In January, the average number of days during the past ten years on which there have been falls of 20 degrees or more in temperature in 24 consecutive hours, and to a minimum of 30 degrees or less, was 35 in February; in March, 2; showing conclusively that what is known as the "Dakota blizzard" seldom reaches this far south, and when felt here its force has been spent.

The heat of summer is an important factor in the climate of any section, and therefore the following table will be of interest:

Number of days on which the temperature was above 90 degrees during the past ten years.

Year.	June.	July.	Aug.	Sept.
1888	1	14	5	0
1889	0	7	0	0
1890	8	12	5	0
1891	2	1	9	0
1892	2	8	8	0
1893	2	9	4	10
1894	3	8	9	1
1895	0	1	1	2
1896	0	11	18	5
1897	1	14	9	11

The night temperature is a matter of much moment not only to invalids and aged people whose recuperative powers have been enfeebled, but also to the business man and the laborer, to whom the period of rest and relaxation from toil, when exhausted nature renews its energy is of vital interest. Experience has demonstrated that in this climate a night temperature of 70 degrees or less insures a good night's rest, and the following table will be of interest in this particular:

Number of days during the past ten years on which the temperature at night remained above 70 degrees.

Year.	June.	July.	Aug.	Sept.
1888	0	10	8	0
1889	0	7	0	0
1890	8	10	8	0
1891	1	0	8	0
1894	1	6	6	0
1893	1	2	0	2
1894	4	1	8	0
1895	1	5	1	8
1896	1	9	18	0
1897	6	18	6	7

Maximum and minimum temperature and the monthly averages for the following years 1888 to 1897:

Years.	Months.	Maximum	Minimum	Mean
1888	January	68	11	28
1889	"	60	4	36
1890	"	74	4	39
1891	"	61	14	36
1892	"	59	10	28
1893	"	65	0	30
1894	"	70	17	36
1895	"	70	12	28
1896	"	64	4	35
1897	"	65	1	37
1888	February	69	5	38
1889	"	65	1	33
1890	"	76	2	40
1891	"	72	6	36
1892	"	66	22	41
1893	"	60	1	33
1894	"	59	2	32
1895	"	66	17	25
1896	"	71	13	38
1897	"	72	10	38
1888	March	83	13	43
1889	"	74	19	46
1890	"	75	6	43
1891	"	68	9	40
1892	"	79	8	41

Years.	Months.	Maximum.	Minimum.	Mean.....
1893....	March	81	3	44
1894....	"	82	13	50
1895....	"	86	10	44
1896....	"	76	14	40
1897....	"	76	14	47
1888....	April	84	31	60
1889....	"	92	35	57
1890....	"	88	32	58
1891....	"	82	26	58
1892....	"	85	29	55
1893....	"	88	31	58
1894....	"	87	34	58
1895....	"	84	34	58
1896....	"	85	28	63
1897....	"	81	34	55
1888....	May	82	34	63
1889....	"	86	37	63
1890....	"	88	36	63
1891....	"	86	39	62
1892....	"	83	36	63
1893....	"	84	40	63
1894....	"	87	38	64
1895....	"	86	40	63
1896....	"	86	47	70
1897....	"	84	39	63
1888....	June	92	50	72
1889....	"	96	48	67
1890....	"	86	54	70
1891....	"	92	57	73
1892....	"	91	50	73
1893....	"	90	51	72
1894....	"	94	48	74
1895....	"	89	56	73
1896....	"	89	50	72
1897....	"	91	46	73
1888....	July	99	62	79
1889....	"	92	56	77
1890....	"	95	59	78
1891....	"	91	58	72
1892....	"	96	54	75
1893....	"	96	61	77
1894....	"	97	56	75
1895....	"	91	55	73
1896....	"	95	57	77
1897....	"	95	56	78
1888....	August	97	54	74
1889....	"	89	57	77
1890....	"	94	56	74
1891....	"	94	44	73
1892....	"	95	50	76
1893....	"	92	48	74
1894....	"	97	55	75
1895....	"	91	59	75
1896....	"	100	57	77
1897....	"	98	52	76
1888....	September	89	40	66
1889....	"	86	38	64
1890....	"	87	38	63
1891....	"	90	44	71
1892....	"	90	44	69
1893....	"	102	40	72
1894....	"	92	42	68
1895....	"	92	37	71
1896....	"	92	40	67
1897....	"	93	44	76

Years.	Months.	Maximum	Minimum	Mean
1888....	October	82	38	54
1889....	"	84	32	57
1890....	"	84	29	56
1891....	"	87	30	57
1892....	"	85	30	59
1893....	"	88	31	55
1894....	"	84	32	59
1895....	"	76	28	53
1896....	"	83	33	55
1897....	"	90	36	66
1888....	November	79	27	43
1889....	"	71	14	41
1890....	"	78	29	45
1891....	"	78	10	41
1892....	"	67	24	43
1893....	"	72	14	43
1894....	"	72	14	45
1895....	"	70	16	43
1896....	"	74	9	44
1897....	"	77	18	46
1887....	December	64	5	33
1888....	"	60	18	38
1889....	"	74	18	52
1890....	"	64	11	40
1891....	"	65	18	42
1892....	"	72	10	38
1893....	"	67	7	39
1894....	"	68	2	35
1895....	"	60	4	36
1896....	"	68	16	42

Annual mean for the decade 55 degrees.

The seasonal conditions as affected by the humidity of the atmosphere in this locality favor the growth and maturity of all cereal crops, while the soil conditions in connection with the liberal rainfall seem especially adapted to the true growth.

The following table shows the rainfall by months during the past decade, and the average humidity of the air :

Years.	Month.	Rainfall inches.	Humidity 8 a. m....	8 p. m....	Mean ....
1888....	January	1.42	84	80	82
1889....	"	2.45	86	76	81
1890....	"	5.51	87	79	83
1891....	"	2.10	85	74	80
1892....	"	3.28	82	70	76
1893....	"	.84	83	67	75
1894....	"	2.82	79	68	73
1895....	"	2.33	80	72	76
1896....	"	1 50	81	69	75
1897....	"	6.47	82	76	79

Years.	Month.	Rain fall inches..	Humidity 8 a. m....	8 p. m....	Mean.....
1888 ...	February	1 22	88	79	81
1889....	"	4 88	84	75	80
1890....	"	5 22	86	79	82
1891....	"	2.80	81	70	75
1892 ...	"	3.71	82	72	77
1893....	"	2.19	84	70	77
1894....	"	2.28	77	66	72
1895 ..	"	.81	81	73	77
1896 ..	"	2.25	78	60	69
1897....	"	4.10	84	71	78
1888....	March	2.46	82	73	78
1889....	"	5.92	83	68	76
1890....	"	4.24	77	64	71
1891 ...	"	1 47	76	67	72
1892....	"	3 84	80	65	72
1893....	"	3.02	76	62	69
1894....	"	3.62	78	51	62
1895...	"	4.70	74	58	66
1896....	"	8 40	81	62	72
1897....	"	5.91	83	67	75
1888 ...	April	1.82	70	59	64
1889....	"	4.41	77	57	67
1890....	"	8.57	77	60	69
1891....	"	4 82	74	56	65
1892....	"	4.56	75	55	65
1893....	"	8.82	68	57	62
1894....	"	4.16	68	52	60
1895....	"	1.10	68	50	60
1896....	"	3.95	80	60	70
1897....	"	3.78	77	56	66
1888....	May	7.86	81	68	74
1889....	"	4.84	82	66	74
1890....	"	5.81	78	63	70
1891....	"	3.78	74	62	68
1892....	"	9.90	86	69	77
1893....	"	5.79	78	60	69
1894....	"	6 48	78	58	68
1895....	"	3.54	78	61	69
1896....	"	11.46	82	66	74
1897....	"	2.45	72	54	63
1888....	June	6.11	86	78	82
1889....	"	5.80	84	72	78
1890....	"	1.33	78	62	70
1891....	"	6.90	83	73	78
1892....	"	4.97	82	64	73
1893....	"	4.40	80	69	75
1894....	"	2.26	76	58	67
1895....	"	3 87	82	66	74
1896....	"	2.81	90	65	77
1897....	"	5.36	81	64	73
1888....	July	0 50	80	63	72
1889....	"	6.58	85	70	78
1890....	"	4.25	77	64	71
1891....	"	5.21	83	70	76
1892....	"	5.18	83	71	77
1893....	"	5.79	81	68	74
1894....	"	2.91	74	57	65
1895....	"	7.86	90	78	84
1896....	"	2.98	78	62	70
1897....	"	2.48	87	69	78

Years.	Month.	Rain fall inches...	Humidity 8 a m....	8 p. m....	Mean.....
1888....	August.....	7.97	86	75	80
1889....	"	2.70	84	72	78
1890....	"	8.21	86	75	81
1891....	"	4.28	86	68	77
1892....	"	8.88	84	66	75
1894....	"	1.11	77	62	70
1894....	"	1.75	78	57	67
1895....	"	4.57	88	74	81
1896....	"	3.04	76	60	68
1897....	"	1.48	86	65	76
1888....	September.....	1.89	84	69	76
1889....	"	2.01	87	77	82
1890....	"	8.11	91	82	87
1891....	"	1.29	76	57	67
1892....	"	0 96	96	61	72
1893....	"	5.91	70	58	61
1894....	"	3.52	85	60	77
1895....	"	3.66	84	71	77
1896....	"	4.12	88	64	74
1897....	"	0.37	87	64	76
1888....	October.....	5.07	84	68	76
1889....	"	2.25	82	66	74
1890....	"	3.97	83	68	76
1891....	"	0.77	76	56	66
1892....	"	3.68	82	61	71
1893....	"	1.15	78	53	63
1894....	"	1.87	78	52	62
1895....	"	0 78	67	48	58
1896....	"	2.50	84	61	73
1897....	"	0.98	76	55	66
1888....	November.....	3.78	86	78	82
1889....	"	5.62	86	72	79
1899....	"	2.41	79	62	70
1891....	"	5 39	84	71	78
1892....	"	1.84	80	67	72
1893....	"	1.54	77	59	68
1894....	"	1.90	71	48	59
1895....	"	3.23	82	66	74
1896....	"	2.09	84	68	76
1897....	"	1.77	78	60	69
1887....	December.....	2.89	86	81	82
1888....	"	2.52	83	74	78
1889....	"	1.06	84	74	79
1890....	"	1 95	80	68	72
1891....	"	1.85	80	64	72
1892....	"	8.10	88	80	84
1893....	"	0 99	78	64	71
1894....	"	2 28	78	67	72
1895....	"	11.02	84	72	78
1896....	"	0.79	75	64	70

SUNSHINE.

The claim is not made from the Ozark plateau that the skies of this section outrival in brightness those of "Sunny Italy," but it is asserted that the average number of clear days in Southwest Missouri will compare very favorably with any section of the Missouri valley, and as this feature of its climatic conditions is one of its greatest charms, the following table giving the number of clear, partly cloudy, cloudy and rainy days during the decade from 1887 to 1897 will be of interest:

	Clear.	Partly cloudy.	Cloudy.	Rainy.
January	91	115	104	90
February	84	86	118	104
March	85	118	107	115
April	97	122	81	106
May	85	150	75	119
June	79	179	42	112
July	99	165	50	101
August	121	151	88	87
September	150	99	51	69
October	168	86	56	84
November	106	94	100	89
December	103	97	111	84

ACKNOWLEDGMENTS.

The generous assistance and uniform courtesy accorded to the writer in the work of preparing this report made the individual acknowledgment of favors almost impossible, but this opportunity is gladly taken to express a general sense of obligation to all who have furthered the pursuit of geological studies in this region, as well as a special appreciation of aid given by the following persons:

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Colonel John E. Phelps, who has been active in the development of the lead and zinc industries of this region, has contributed much indispensable information.

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Mr. J. W. Blankinship has made additions to the list of trees of Greene county.

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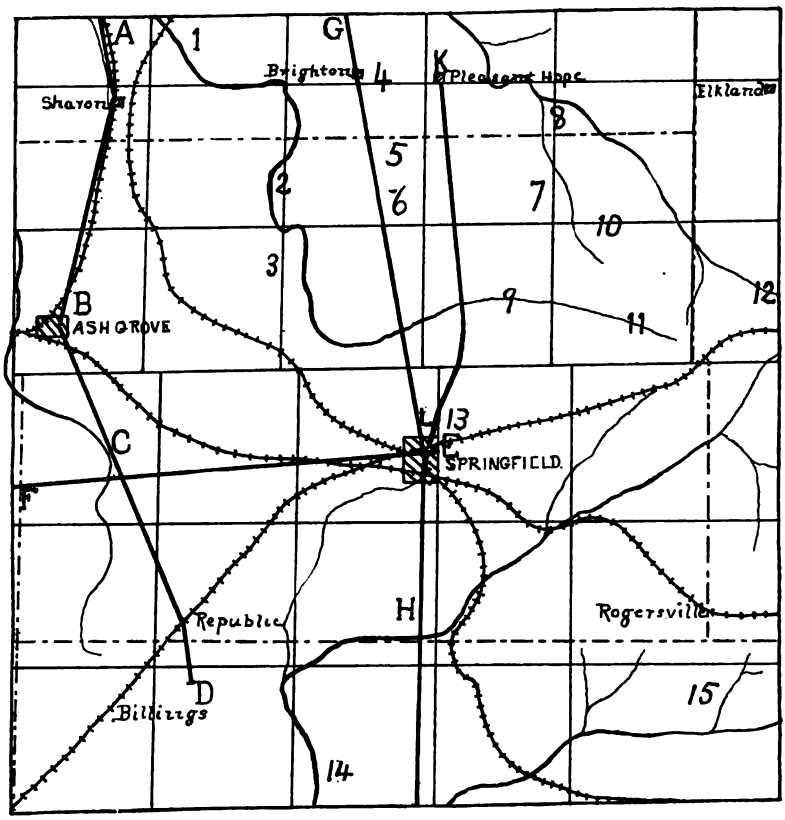
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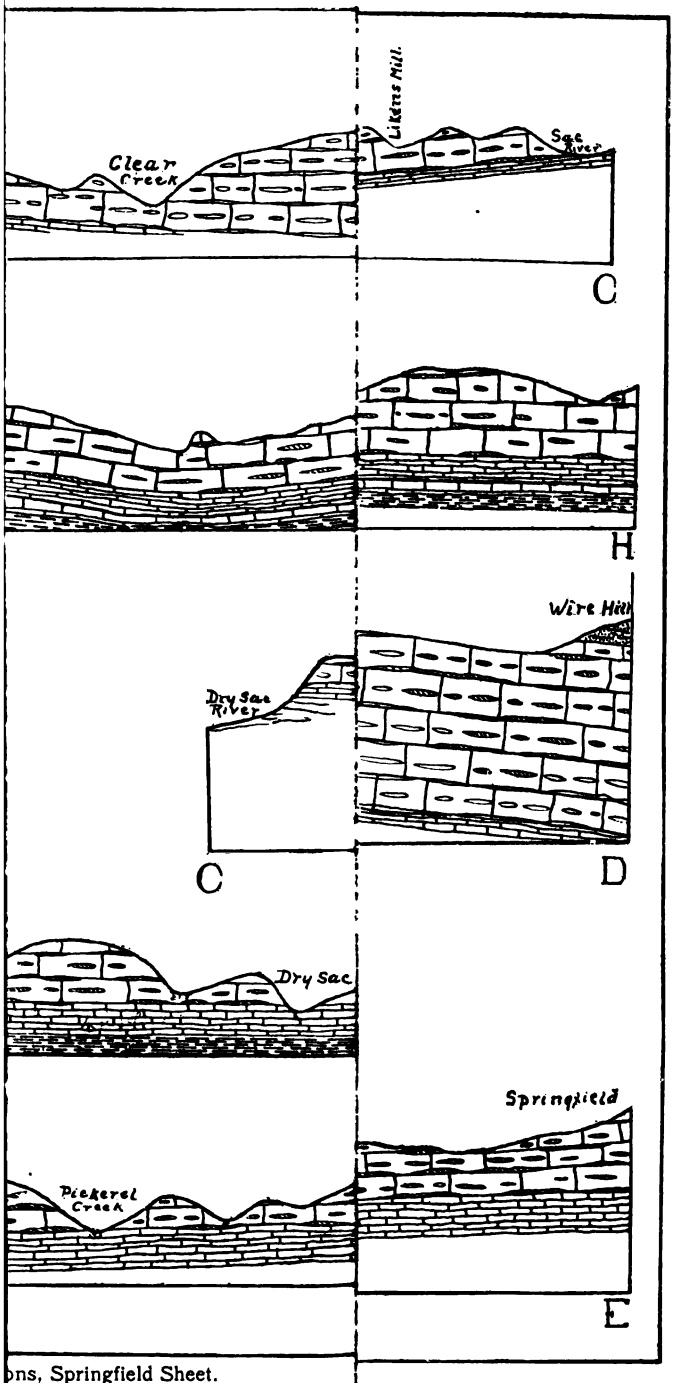

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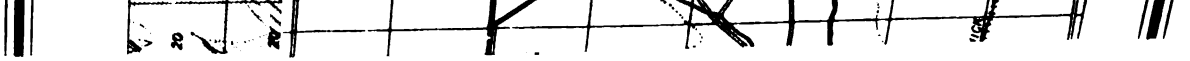

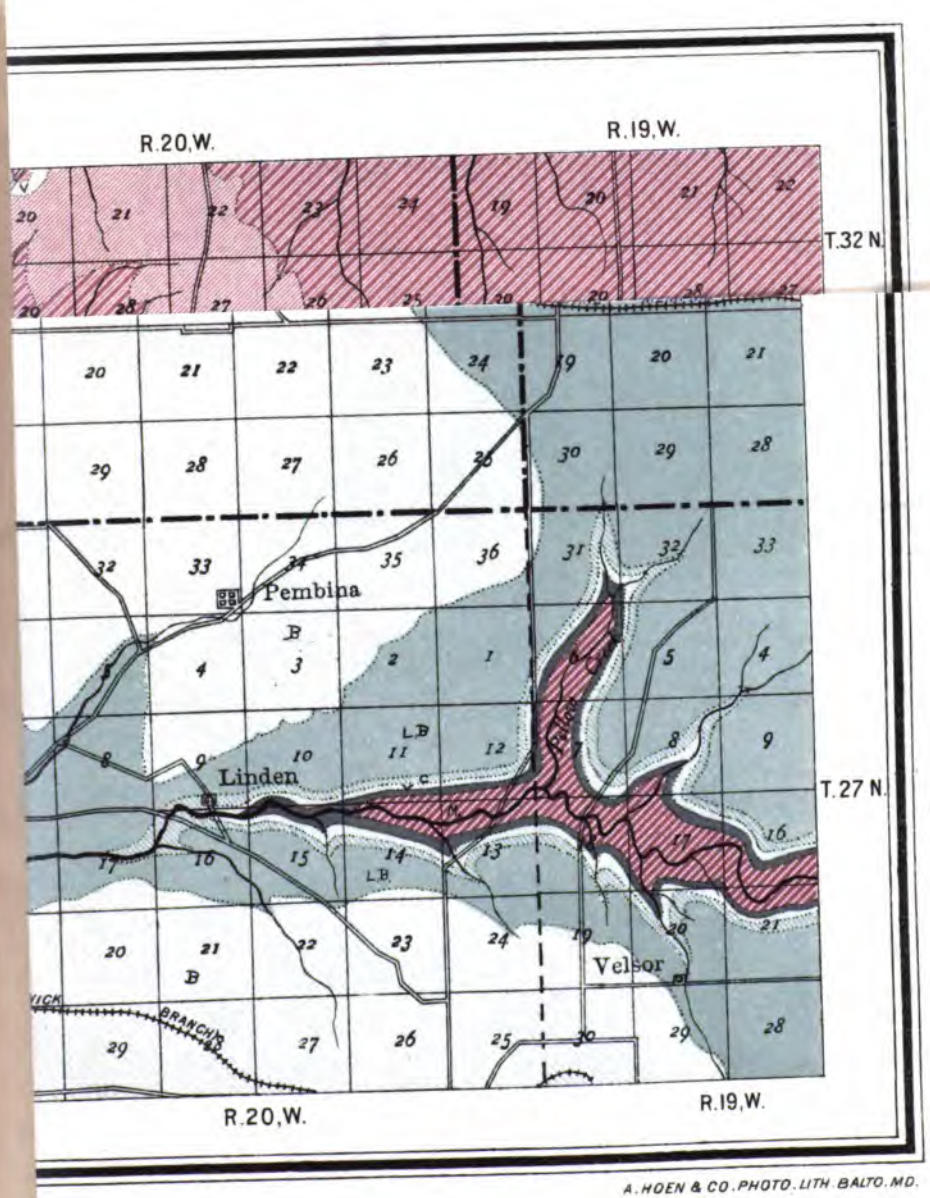

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GEOLOGICAL DESCRIPTION

OF THE

CLINTON SHEET.

GEOLOGY OF THE CLINTON SHEET.

BY CURTIS FLETCHER MARBUT.

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INTRODUCTION.

LOCATION AND AREA.

The Clinton sheet occupies the western half of Henry county, and takes its name from the city of Clinton its most important industrial center. The area covered is a quadrilateral of 15′ extent in latitude and longitude. It is included between the lines 38°15′ and 38°30′ of latitude, and 93°45′ and 94° of longitude west of Greenwich. Its position in the state is west-central. It lies about 40 miles east of the Kansas state line, 150 miles from the southern boundary of Iowa, 180 miles from the Mississippi river, and 120 miles from the northern Arkansas line. The location with reference to the county midline is shown in the subjoined diagram (figure 1). The area is about 230 square miles.

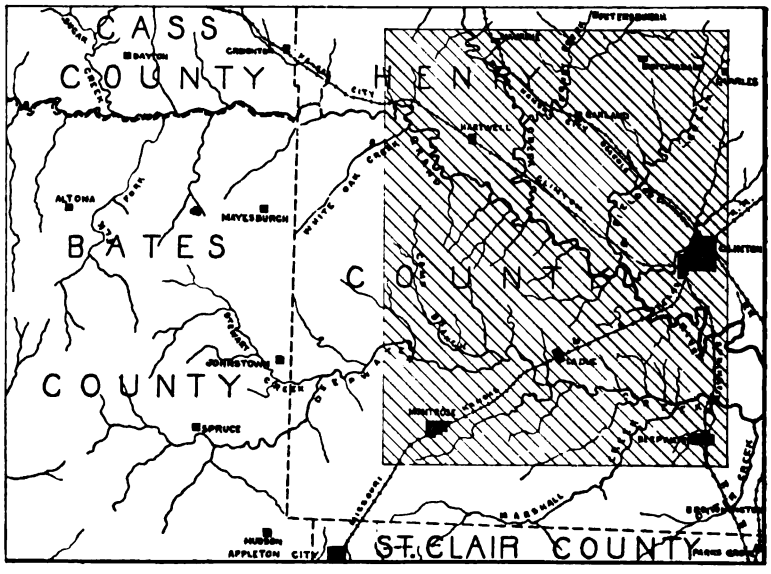

Figure 1. Position of the Clinton Sheet.

PHYSIOGRAPHY OF THE REGION.

GENERAL SURFACE RELIEF.

The rocks of western Missouri dip northwestward at a slightly greater rate than the inclination in the northwestern part of the state. They are all sedimentaries of Paleozoic age, undisturbed by faults, folds or eruptive intrusions. They consist of shales, sandstones and limestones dipping westward in conformity with the general slant of the Ozark slope. The present topographic features are characteristic of a well advanced stage of erosion on rocks of similar nature and arrangement.

Topographic features everywhere depend upon the stage of advancement in the cycle reached by the destructive forces. In the early part of the cycle the features are dominated by the constructional form. As the cycle progresses the destructional forms become more and more prominent, gradually destroying all signs of the constructional forms. The greatest variety of relief will exist about the time of the later disappearance of the constructional form. The destructive forces are then more active. The soft rocks waste away very rapidly, while the harder beds show a relatively small amount of erosion. The soft beds waste away with lowland belts running along their strike, while the harder beds are left in relief as ridges. This is the result regardless of the direction of the drainage. The exact details of relief at this stage varies with the rock structure.

In a region of gently dipping beds of alternately hard and soft rocks the features at maturity of the cycle are characterized by belts of lowland and highland, the former following the strike of the soft rocks, the latter, that of the hard beds. The highlands slope gradually in one direction, down the dip of the

beds, and generally, for some distance downward from the crest, conform to the surface of the hard bed. In the other direction the slope is steep and lies across the broken edge of the hard bed. The lowlands pass imperceptibly upward into the highland belt on one side, and are abruptly terminated on the other side by the escarpmented edge of the highland.

The conditions as to structure and character described above obtain in western Missouri in the district covered by the Clinton sheet. The rocks dip gently northwestward and are alternately hard and soft. The lowest rocks involved in the topography near the Clinton area are the resistant chert-bearing lower Carboniferous limestones. They constitute one of the most pronounced series of resistant beds in the region. These are overlain by the basal sandstones and shales of the coal measures and constitute a series of soft beds. These are in turn overlain by more resistant limestones. Still higher is another setof shales capped in turn by limestone, near the western boundary of the state. These rocks strike northeastward and give rise to a similar trend of the main geographic features, notwithstanding the streams all flow eastward. The eastern edge of thelower Carboniferous limestones lies well upon the sides of the Ozark dome and far east of Henry county. The broad westwardly sloping plain, which extends from its eastern outcrop and corresponds to the upper surface of its beds, is one of the most pronounced topographic units of the state. It dips gradually westward until it passes below drainage level and is then overlain by the soft coal measure shales which are worn down into a lowland. The belt is bordered northwestwardly by the eastern edge of the next overlying hard bed which forms an escarpment, with a moderately steep eastward face and with a slight slope in that direction. This is succeeded westward by another lowland worn on soft beds, which is also bordered westwardly by another eastward facing escarpment. The latter is the eastern edge of a plateau which extends westward into Kansas.

LOCAL PHYSIOGRAPHY.

The area occupied by the Clinton sheet is traversed by two of the belts just named. The broad sloping plain of lower Carboniferous rocks is terminated by the burial of its controlling beds within two miles of where Grand river crosses the

Figure 2. Physiographic Belts of the Clinton Area.

eastern border of the area. The next belt, which is determined by the soft shales of the coal measures, constitutes a lowland about at grade, and embraces more than one-half the area of the district. The western border of the lowland enters the sheet near the southwestern corner and extends thence northeastwardly nearly to Grand river near the center of the area. Thence it turns westward making a deep embayment up the stream named and its important tributaries, returning and crossing the eastern border about three miles north of Clinton. All the area of the sheet lying southeast of this line is included within this zone. It has been named the Nevada lowland, because of its prominent development in the vicinity of the county seat of Vernon county. All the rest of the area is occupied by the next succeeding belt of upland. That part within the Clinton sheet includes a part of its ragged and faintly developed eastward facing escarpment, and a small portion of the upper surface. The distribution of the physiographic belts over the area is shown in the accompanying cut (figure 2).

That part of the Nevada lowland included within the area of the Clinton sheet is a low and very gently undulating plain. Its elevation above the floodplains of Grand river and the Deepwater is less than 75 feet, and over large areas it is less than 50 feet. The whole area is nearly down to grade. The streams have broad floodplains bordered by gently sloping bluffs, excepting at points where the watercourses now flow against them.

In the southeastern corner of the sheet lenses of sandstone occur interbedded with the softer shales. Where these are cut by the streams the floodplain is very much narrower than in the shale. When they are of considerable size and have been uncovered they are left in relief, producing some irregularity in the otherwise smooth plain. Deepwater creek cuts a lens of this kind, two and one-half miles northwest of Deepwater village.

The escarpment bounding the Nevada lowland on the northwest is not a conspicuous feature within the area of the Clinton sheet. It is noticeable only in one place. In the

western part, just south of Grand river, the steep face, turned toward the river is truly escarpment-like and about 100 feet high. Elsewhere it is represented by much more gradual slopes. It is marked by a series of low mounds a few miles west of Montrose. The upland above the escarpment is a broad, even or gently undulating plain about 860 feet above tide water.

The floodplains of the streams form so considerable a part of the total area of the sheet that they may be considered one of the features of its relief. Grand river meanders through a floodplain averaging almost two miles in width, while that of Big creek is but little narrower. The probabilities are that this is due to the soft shale in which the plains are cut. The valley of Grand river, only a few miles east of the area of the sheet, becomes very narrow and remains so to its mouth. The explanation of the contraction of the valley is undoubtedly found in the relatively resistant lower Carboniferous limestone in which it is cut. The wide valley above is only the result of work for the same length of time in a much more easily eroded material.

One other explanation for the existence of these wide floodplains has been suggested. It is based upon a study of the meanders of this stream and those of the Osage through the lower Carboniferous and other limestones to the east. It explains these features by supposing them to be inherited floodplain meanders of a former cycle of topographic development, when the country stood lower than it now does and when it was reduced to a lowland plain of denudation. While at this stage the streams meandered through wide floodplains. When the present cycle was initiated by an uplifting, the cutting downward of the stream commenced first at the lower margin of the uplift or at the seashore. It worked gradually backward, that part of the stream above the actively cutting portion continuing to meander on the old floodplain. The explanation suggested supposes that this backward cutting of the stream has just reached the eastern part of the area of the Clinton sheet, and that Grand river, within this area flows in

its floodplain of a former cycle of development. If this were the true explanation there would be expected a more rapid fall in the stream just below where it cuts below the old floodplain, the floodplain of the former cycle which is supposed to be preserved in the wide floodplain of that stream in the area of the sheet. There should be also the remnants of the old floodplain as benches above the present gorge of the river down-stream from the point now reached in its backward cutting.

Instead of a greater fall on entering the meandering part of its course there is less fall. According to accurate leveling, the total fall from the eastern side of the Clinton area to a point about fifteen miles east, is only about 35 feet, and in this distance some of the most symmetrical meanders found anywhere along the course of the stream are included; while from the western side of the area to its eastern side the fall is about 40 feet and, this stretch is entirely within the supposed old floodplain. There is no sign whatever of an old floodplain above the gorge of the stream east of the area. At first the bluffs are low, and from their top, the country is nearly level, but as the lower Carboniferous rocks rise eastward the apparent bench rises also.

It cannot be explained by supposing the "fall-line" to have progressed upward until it now lies within the Clinton area. If this were true, at least the eastern part of the area should show an incipient benching of the present floodplain, and a corrasion of the channel of the stream, which does not appear. There is a rather clearly defined bench on the lower course of Deepwater creek, in the vicinity of Deepwater, but the work done at the lower stage is too great to allow the reference of change of grade of the stream to so recent a date as the above suggestion would require.

The extreme width is considered to be due to the extremely soft rocks in which the valley is cut. It contracts both eastward and westward immediately upon entering a strip of more resistant beds.

The hypsometry of the area is shown below (figure 3):

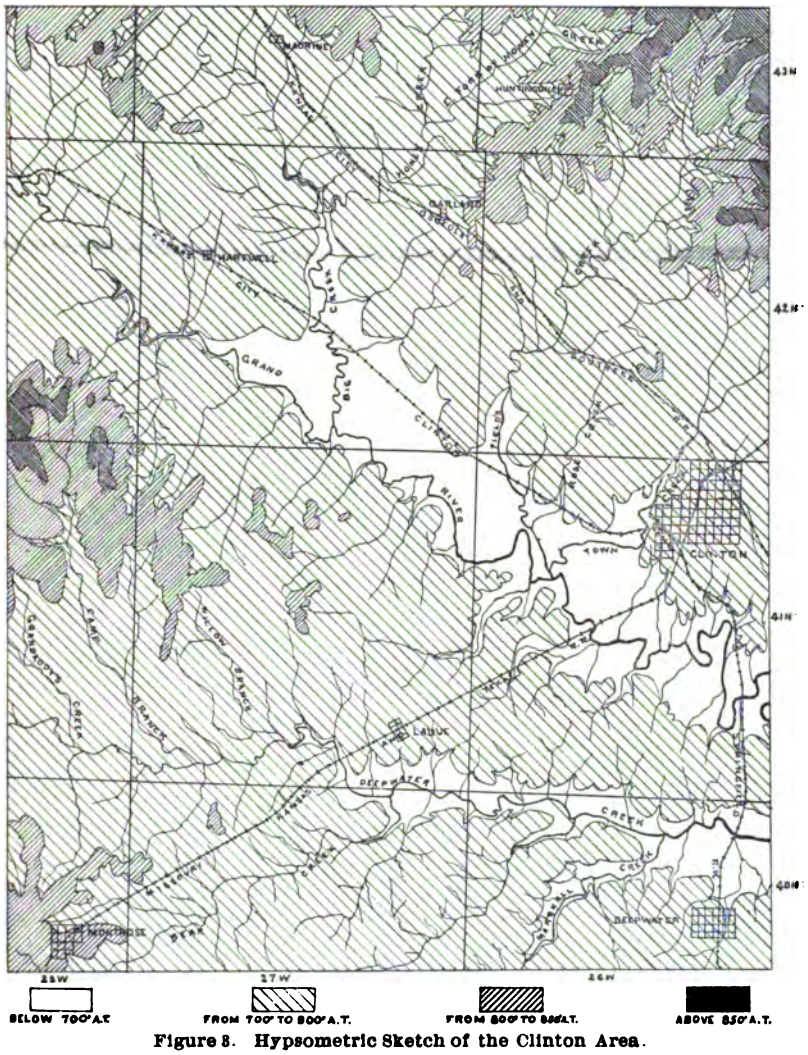

Figure 8. Hypsometric Sketch of the Clinton Area.

DRAINAGE.

The entire area forms part of the drainage basin of the Osage river. All the streams are small, none being navigable; and all excepting Grand river, becoming dry, or nearly so, during a period of protracted drouth.

Grand River rises in eastern Kansas beyond the western limits of the state. It flows in a nearly due easterly course, traversing the Clinton area about half way between its northern and southern boundaries and reaches the Osage about 25 miles east of the eastern line of the sheet. It has a fall of about three feet to the mile. Its channel lies about 18 feet below the level of its floodplain. It winds through the latter in a very irregular course. There is very little, if any, trace of symmetrical meandering. It hugs its southern bluff through almost the whole of its course. Frequently it overflows its banks and spreads over the whole floodplain, making the reclamation of this large area of land a difficult matter.

Deepwater Creek rises in Bates county and flows across the southern part of the area in an easterly direction. It falls into Grand river about two miles east of the town of Deepwater. Its floodplain varies greatly in width, widening and narrowing as the stream crosses belts of soft shales and cuts resistant sandstone beds. Immediately north of the town its floodplain is more than a mile wide. Two miles above this it is but a few hundred yards wide. Beyond, the valley again expands.

Big Creek rises in Cass county, flows southeastwardly across the Johnson county line and falls into Grand river within the limits of the Clinton sheet. That part of it flowing within the area of the sheet is flanked by alluvial plains, second only to those along Grand river. Occasional ponds scattered over the bottom lands show former courses of the stream. They are not numerous nor recent. None have the appearance of ever having been of ox-bow shape. The creek has a fall of about three feet to the mile.

Honey Creek is a small tributary of Big creek, rising a few miles north of the area.

Marshall Creek is a tributary of Deepwater creek from the south; and *Fields* and *Town* creeks are tributaries of Grand river rising within the area of the sheet.

FORESTRY.

The woodland area of the sheet is confined now, and was at the time of the first settlement of the county, to the imme-

diate vicinity of the streams or to small areas of hill-land in the northwestern part of the district. The number of species is not large, a result naturally to be expected from the uniformity of conditions over the area. The principal forest trees which are the most abundant and which are of importance from an economic point of view are:

Black oak, *Quercus velutina*, Linn.
White oak, *Quercus alba*, Linn.
Black jack oak, *Quercus nigra*, Linn.
Red oak, *Quercus rubra*, Lurn.
Pin oak, *Quercus palustris*, Du Roi.
Laurel oak, *Quercus imbricaria*, Michx.
Post oak, *Quercus minor* (Marsh)
Burr oak, *Quercus macrocarpa*, Michx.
Shell-bark hickory, *Hicoria ovata* (Mill.)
Black hickory, *Hicoria alba* (L.) Britton
American elm, *Ulmus americanus*, Linn.
Slippery elm, *Ulmus pubescens*, Walt.
White maple, *Acer saccharinum*, Linn.

Of rare occurrence are:

Box elder, *Acer negundo*, Linn.
Black walnut, *Juglans nigra*, Linn.
Cottonwood, *Populus monilifera*, Ait.
Sycamore, *Platanus occidentalis*, Linn.
Locust, *Gleditschia triacanthus*, Linn.
Wild cherry, *Prunus serotina*, Ehrh.
Buckeye, *Æsculus glabra*, Willd.
Redbud, *Cercis canadensis*, Linn.

The area covered with forest growth includes a narrow strip along the channel of the streams, a small area in the vicinity of Clinton (Tp. 42 N., R. XXVIII W., Sec. 36, NW. qr.), and the rugged lands west of Huntingdale. The growth of the bottoms is principally elm, laurel and pin-oak, with less frequent burr-oak, hickory, post-oak, walnut and maple, the latter being abundant on the banks of the streams, but always in the most recently formed alluvium. In the vicinity of Clinton and in all the uplands where the drainage is good, the growth is black oak, with scattering white oak saplings in the cooler argillaceous soils. On the sandy soils of the uplands black jack-oak is almost the only forest tree. The timber of the area is used but little. The quantity that is large enough for lumber is too small to encourage a development of a lumber

industry and there is no demand for it for fuel, on account of the abundance and cheapness of coal.

STRATIGRAPHY.

MAIN CHARACTERISTICS OF THE REGION.

The rocks of the region are wholly sedimentary. They consist of Paleozoic and Recent deposits, the former constituting the indurated rocks of the region and the latter the soils and alluvial deposits. The Paleozoic rocks belong to the lower Carboniferous and coal measures. They consist of limestones, shales and sandstones. They lie in beds, many of great horizontal extent, the position of which is but little different from that in which they were originally deposited. They all have a slight general northwestward dip, varying in degree at different places. The general westward slant in some cases is reversed, giving a southeastern dip. These are all of small extent and barely perceptible without instrumental surveying. The dips are everywhere so slight that to the unaided eye the beds appear horizontal. The rocks outcrop on the surface in zones, having a northeastward and southwestward trend, perpendicular to the dip of the beds. The lower beds constitute the eastward part, while the higher beds outcrop successively further and further westward. The following is a tabular arrangement of the strata represented in the area of the sheet:

Table of Strata.

SYSTEM.	SERIES.	FORMATIONS.
Recent.		Alluvium.
Carboniferous.	Des Moines.	Pleasanton shales.
		Henrietta limestones.
		Cherokee shales.
	Mississippian.	Augusta limestones.

CARBONIFEROUS.

MISSISSIPPIAN SERIES.

Augusta Limestone. The series includes the lowest rocks in the Clinton district. The beds overlie rocks of Silurian age but the latter do not rise to the surface. The lower Carboniferous rocks of the region consist of cherty and shaly limestones, shales and sandstones, but only the upper beds are here exposed—the heavily bedded, coarse-grained crinoidal limestones, carrying chert in nodules irregularly distributed throughout the beds, and in layers more or less continuous between the separate beds of limestone. The same lithological characters are persistent over a great part of southwestern Missouri. These beds belong to the Burlington division of the Augusta. In some places, especially in the extreme southwestern part of the state some of the Mississippian beds probably belong in the next overlying division, the Keokuk. It was probably deposited over the whole area but during the time which elapsed between the deposition of the last of the lower Carboniferous rocks of the region and the first of the coal measures the former were subjected to erosion. They were eroded down far enough to remove all or nearly all of the rocks overlying the Burlington. The thickness of the lower Carboniferous rocks in southwestern Missouri varies from 100 to 300 feet.

The surface upon which the coal measures were deposited was an old land surface. The junction between the two formations is therefore an unconformable one.

DES MOINES SERIES.

The upper Carboniferous of Missouri is readily divisible into two great divisions, the Des Moines and Missourian formations. The only one of these divisions that needs consideration here is the lower. The upper division exists south of the Missouri river but does not reach the Clinton area by several miles.

The Des Moines formation consists of shales, sandstones, a few thin limestones and coals. The proportions of the various kinds of rock vary with the subdivision. The whole series in this part of the state consists of three formations, the Cherokee, the Henrietta and the Pleasanton.

Cherokee Shales. The lowest division includes the shales and sandstones, which are exceptionally well exposed along the Marmaton river, in Vernon county. The river rises in the rocks of the next higher formation and in its course it traverses nearly the whole thickness of the formation as developed in Vernon county. Where the Marmaton flows into the Osage there are probably not many feet of coal measures underlying the channel. The Osage river has cut through them at Papinsville, only a few miles below. The formation thickens southwestward, and in Cherokee county, Kansas, which may be regarded as the typical locality, they are 450 feet thick.* In Vernon county, Missouri, Broadhead† determined the thickness to be little more than 300 feet, and in Henry county they are 150 to 200 feet thick. It is probable that the northeastward thinning is apparent only. Drill-hole records indicate a slight thickening northward. In southwestern Missouri and southeastern Kansas they have been exposed by the removal of a wide belt of the overlying rock. Northeastward the amount of uncovering is smaller, so that the thickness exposed is not so great. They have not been uncovered very far back from their original landward margin. Only the thin edge is exposed.

The most abundant rock in the formation is a soft shale. Near the base is often a conglomerate, though the beds of this character are not heavy. These graduate upward into sandstones and the latter into shales. The sandstones are the most persistent over large areas, even near the base of the series. They occur generally in lenticular masses in the shales. In Vernon and Barton counties the sandstone beds are a rather prominent feature of the formation. In Henry county

*Univ. Geol. Sur. Kansas, vol. 1, p. 40, 1896.

†Geol. Sur. Missouri, 1873-4, p. 101, 1874.

they are less so. Everywhere they are most abundant near the base of the formation.

From a purely stratigraphic point of view the coal and underclay beds are unimportant. They are generally associated with each other, but are never more than a few feet in thickness. They are not persistent over large areas. All the workable coals lie in basins of varying size, but none of them extending entirely across the area occupied by the Cherokee formation.

The limestone beds are very unimportant. They occur in small lenticular masses underlying areas of a few acres; but in one or two instances thin beds are persistent along the strike for more than twenty-five miles. This occurs, however, well up from the base of the formation. They are all thin and are impure. They are very often highly bituminous, and generally highly fossiliferous.

Henrietta Formation. This term is applied to a succession of rather persistent beds which overlies the Cherokee shales. The beds vary in thickness and character along the strike, though not so much as those of the Cherokee formation. The formation has not been studied sufficiently to determine its character over its whole extent nor to locate everywhere its exact upper limit. Its lower limit is clearly defined in Henry county and reasonably so along the rest of the outcrop. The formation is made up of shales and limestones with a thin bed or two of coal and an occasional sandstone. The shales make up the greater part of the section, but the limestones on account of their greater resistance to erosion, are the most conspicuous features of the formation. Broadhead's section* of the formation in Bates county includes about 50 feet of strata, the top being a five-foot, and the bottom a three-foot bed of limestone, and the section between the two consisting of shales. In Henry county the base is marked by a limestone 2 to 8 feet thick. Above this, the formation consists of sandy and clay-

*Geol. Sur. Missouri, 1873-74, pp. 159-160, 1874.

shales with one or two beds of limestone. The top has not as yet been located in the area.

The formation is essentially the northeastward extension of the Fort Scott and Pawnee limestones and the shales included between them in Kansas, as defined by Swallow* and later by Haworth†. So far as they have been studied in Missouri they do not present the great persistence in thickness and character that they show in Kansas. In Bates county, Missouri, the two limestones are clearly separated. In Henry county the upper one has separated into two or three thin beds, while the lower one has remained about the same. In Johnson county the lower one reaches a thickness of more than 10 feet, while the upper one, unless the two have come together forming one, is not distinguishable.

From Kansas the Henrietta formation enters Missouri in Bates county a few miles south of the Osage river. It runs northeastward in a belt from 5 to 15 miles in width, through Bates, Henry and Johnson counties. North of this it has not as yet been traced, but there is little doubt that it includes the beds associated with the Lexington coal in Lafayette and Ray counties.

Pleasanton Shales. This term is applied to certain shales of reasonable persistence in character and thickness, which stretch across the entire state. They overlie the Henrietta formation and extend upward to the base of the Missourian series. The average thickness is about 200 feet. The formation is made up of sandy and argillaceous shales and sandstone with occasional beds of coal. The formation enters the state in northern Bates county and trends northeastwardly in a belt about 20 miles wide, crossing the Missouri river in the central part of Lafayette county. The Sniabar creek in Lafayette county traverses the whole formation from top to base.

*Kansas Geol. Sur., Prelim. Rep., p. 24, 1866.

†Univ. Geol. Sur. Kansas, vol. 1, pp. 40-43, 1896.

GENERAL FEATURES OF THE AREA.

A generalized section of the rocks of the Clinton district is represented in figure 4. The area of the Clinton sheet is traversed by the Cherokee and Henrietta formations. The Pleasanton shales probably occupy a very small area in the northwestern corner of the sheet and the lower Carboniferous or Mississippian rocks appear in the bed of Marshall creek. Fossils in the chert show that the latter belong to the Burlington division. The Cherokee shales occupy the greater part of the area. They naturally fall into two divisions, an upper and a lower, the top of the latter being the base of the Tebo coal bed. The lower division is a typical shore deposit. The beds are irregular in thickness and of limited lateral extent. Near the base they are made up of sandstones. The beds are not regular and they pass laterally into shales and even into

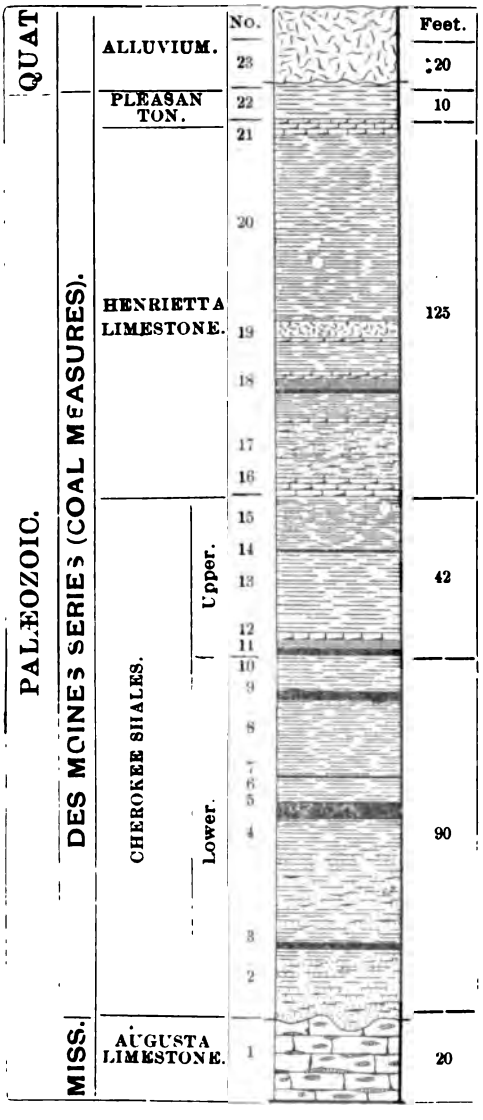

Figure 4. General Geological Section of Clinton Area.

limestones. Shales become more abundant upwards becoming the predominating bed about 50 feet above the base of the formation. The shale pockets in the lower sandstones carry basins of coal, some of them, as the Jordan coal, being several square miles in extent. Ordinarily, however, the coal basins are small. Occasionally a coal bed in one of these basins may have a thin limestone associated with it. The latter graduates laterally into shale and even into sandstone. These thin limestones are often highly ferruginous. A bed of this kind outcrops in the river bank at Gilkerson ford, and also two miles southwest of Hartwell. The most important of these lenticular masses of limestone outcrops on the west bank of Town creek in the northwestern part of the city of Clinton. It is also exposed about half a mile west of this locality in another ravine.

The upper part of the Cherokee shales, extending from the bottom of the Tebo coal to the top of the formation is more evenly stratified than the lower. The beds are more persistent and not so undulatory. They were deposited a short distance off shore and on a smooth sea floor. The inequalities of the old sea bottom had become smoothed over by the filling up of the depressions. The horizon most easily followed in the formation is the Tebo coal. It has been traced along its outcrop entirely across the sheet, excepting a small area in the Grand river valley in the western part. This may due to thinning or to change of character in the direction of the dip, or it may be due to a cover of alluvium. It is probable, however, that it thins out in this direction. This is indicated by wells and by borings at Creighton, about twelve miles northwest of Hartwell. Drill-holes failed to encounter any coal seam which can be correlated with the Tebo vein. The tops of the holes are above the Tebo horizon and the bottoms certainly extend below it.

STANDARD SECTIONS.

The general character of the formation is shown in the following sections which may be regarded as a standard for comparison. The first section is a record of the Central coal shaft

at Deepwater, on the eastern border of the sheet and one mile northeast of the town. The bottom of the shaft is about 25 feet above the base of the coal measures. The interval is made up of shales and sandstones.

Section I. Central Coal Shaft, at Deepwater.

		Feet.
7.	Soil and clay (top of shaft 720 feet above tide water)	15
6.	Sandstone, soft, shaly	6
5.	Shale, blue to black	9
4.	Shale (siliceous and calcareous)	20
3.	Shale	1
2.	Coal	2¾
1.	Underclay (exposed)	1

The rocks exposed at Gilkerson ford were described by Broadhead.* The locality is at the bend in Grand river in the southern part of section 26, about four miles north of Deepwater.

Section II. Bluff at Gilkerson Ford.

		Feet.
8.	Sandstone, buff, shaly (700 feet above tide water)	5
7.	Shale, blue, abounding, in lenticular nodules of clay iron stone, which contain plant remains	2
6.	Coal	1·6
5.	Shale	14½
4.	Coal	½
3.	Sandstone, abounding in Stigmaria	3
2.	Shale, containing numerous ferns and other fossil plants	21
1.	Coal (in river)	3

Section III is exposed in the south bank of Grand river in the northwest corner of section 30, two miles southwest of Hartwell. The top of the section lies about 20 feet below the horizon of the Tebo coal bed.

Section III. Southwest of Hartwell.

		Feet.
10.	Shale, sandy (720 feet above tide level)	8
9.	Coal	¼
8.	Shale	½
7.	Coal	¼
6.	Shale, argillaceous, drab	8
5.	Coal	½
4.	Shale, sandy	4
3.	Shale, dark blue	3
2.	Ironstone, calcareous	⅔
1.	Coal and shale	1¼

* Missouri Geol. Sur., Iron Ores and Coal Fields, part II, p. 17, 1873.

That part of the Cherokee shales lying above the Tebo coal bed is given in section IV, as shown in the western part of the district. The base of this section is less than 20 feet above the horizon of the Tebo coal bed. The interval consists of shales with a four-inch coal bed.

Secion IV. West of Clinton.

		Feet.
6.	Shale, yellow and black (top of Cherokee formation 715 A. T.).	6
5.	Coal	1
4.	Clay and shale	15
3.	Limestone	1
2.	Shale and sandstone	30
1.	Concealed (probably shale)	25

The phase assumed by this part of the formation in the northeastern part of the area is illustrated in section V, which is the record of a shaft near the Missouri, Kansas and Texas railroad, five miles northeast of Clinton.

Secton V. Northeast of Clinton.

	UPPER CHEROKEE	Feet.
13.	Shale	15
12.	Coal	½
11.	Shale and clay	23
10.	Limestone	2½
9.	Shale	2
8.	Coal	2½
	LOWER CHEROKEE.	
7.	Clay and shale	9½
6.	Coal	3
5.	Shale	19
4.	Coal	½
3.	Shale	7
2.	Coal	¼
1.	Shale	13

The Henrietta formation occupies the higher parts of the northern and northwestern portions of the area. The bottom of the formation is at the base of the limestone which lies 6 to 12 feet above the Honey Creek coal bed. The beds are off-shore deposits and are presistent over the area of the sheet. The limestone marking the base of the formation thins slightly southward but is a well marked bed where it leaves the sheet and continues southwestward into Kansas. Shales constitute

the greater part of the formation though the limestones are prominent on account of their greater resistance to erosion. The top of the formation does not appear within the district or it is not as sharply marked by a thick limestone bed, as it is in Lafayette county and in Kansas. At least no bed of limestone within the area has yet been determined to be the upper member of the formation. The thickness is about 100 feet The general character of the formation in Henry county is indicated in the following section which is compiled from several outcrops in the northeastern part of the Clinton area and the northwestern part of the Calhoun district.

Section VI. General Henrietta Section.

		Feet.
12.	Limestone	5
11.	Interval (probably shale)	50
10.	Clay	4
9.	Limestone	1
8.	Shale	8
7.	Limestone	2
6.	Shale, black, fissile	2½
5.	Coal	1
4.	Shale	7
3.	Limestone	1
2.	Sandstone and shale	15
1.	Limestone	5

The Pleasanton formation probably does not occur in the area of the sheet. If at all it is only in a few outliers of shale on the hill-tops in the northwestern part. These do not differ materially from the shales in the other formations, so that their recognition can be based only upon a study of the region west of the Clinton area.

TYPICAL SECTIONS.

SECTIONS IN TOWNSHIP 40 NORTH, RANGES XXVI, XXVII AND XXVIII WEST.

At the extreme eastern edge of the Clinton sheet, half a mile east of Deepwater, and in the district adjacent, coal is mined rather extensively. The rocks encountered in sinking the old Keith and Perry shaft No. 1, according to Mr. Patterson, the superintendent, are as follows:

Section VII. Keith and Perry Shaft, No. 1.

		Feet.
6.	Soil and clay	15
5.	Sandstone, soft, shaly	6
4.	Shale, blue to black	9
3.	Shale, calcareous, "limestone?"	20
2.	Shale	1
1.	Coal	3

The "limestone," No. 3, as reported, is a hard, gray silicious shale which varies greatly in thickness within a short distance, and apparently grades into an argillaceous shale. On exposure to the weather it often appears to be a sandstone, its lamination not being then visible, but in the fresh pieces thrown out of the shaft this structure is marked. About 1500 feet east of this shaft the same bed of coal is mined or rather quarried, after a heavy stripping (sometimes 20 feet) of shale is removed. It is a soft, yellowish or bluish, argillaceous bed having little or no similarity to the "limestone" in the shaft. The record of shaft No. 2, owned and operated by the same company and situated just south of the southern limits of the sheet (Tp. 40 N., R. XXVI W., Sec. 23, NE. qr.) is as follows:

Section VIII. Shaft No. 2, at Deepwater.

		Feet.
5.	Soil and clay (top 750 feet A. T.)	15
4.	Sandstone, shaly	20
3.	"Limestone," (silicious shale)	12
2.	Shale	12
1.	Coal	2¾

The character of No. 3 changes so much toward the bottom of the shaft that the miners call it shale. It is doubtless continuous with the "limestone" in shaft No. 1, but it is changed from a hard silicious shale to a soft more or less argillaceous one.

A short distance south of the town of Deepwater coal was mined a few years ago by stripping. The coal lies at an elevation of about 720 feet A. T. It is probably the same vein that is worked in the shafts but has risen westward, the rise amounting to about 40 feet from shaft No. 1. In section 20,

southeast quarter, a drill-hole was sunk but no coal was reached. The top of the drill-hole is about 720 feet A. T. It is reported that a thin vein of coal was found in a shallow excavation in the ravine 200 yards southwest of the drill-hole and a few feet higher than its top.

West and northwest of Deepwater, along Deepwater and Marshall creeks, sandstone is abundantly exposed but no coal appears. From the stripping just south of Deepwater westward no occurrence of coal is seen east of section 21 of this township. In section 24, northeast quarter, three feet of coal were reported to have been encountered in a well at a depth of 27 feet. The top of the well is about 765 feet A. T. Whether this is a different bed of coal, or only the westward extension of the vein at Deepwater, is not possible to determine. At Deepwater the coal bed rises toward the west. In the well it lies at an elevation of about 740 feet A. T., about 20 feet higher than the coal at Deepwater.

In section 17, southwest quarter, a two-foot bed of coal has been mined by stripping the overlying material, which consists of 15 feet of dark and light colored argillaceous and sandy shale with two feet of sandstone. The coal is now concealed. This is very probably the same that was encountered in the well described above. A coal bed which is probably the same as this one has been mined about half a mile south. It has the same thickness and is overlain by a thin shale, with three feet of sandstone overlying the shale. In section 20, northwest quarter, at a depth of 14 feet, in a dug well, the coal is overlain by sandstone, and under it are eight feet of sandy shale passing into two feet of dark shale and again into sandstone. The bed is about 770 feet A. T.

Near the middle of the east half of the northeast quarter of section 7 is a coal bed two feet thick. Over it are shown about two feet of dark shale. No other rocks are exposed at this point, but sandstone crops out in almost every hillside. At another place about 1500 feet west of this point, a coal bed of about the same thickness is seen. It is overlain by 18 inches of sandstone. At a well in the southeast quarter of

section 6 of this township a two-foot bed of coal was reported at a depth of 18 feet. At all of these places the coal is about 730 feet A. T. Between this group of exposures and that in sections 17, 20 and 21 no coal was seen nor its presence reported. The rocks, consisting of sandstone and shale exclusively, are exposed in many places. They are all rather soft, the shales especially, and a thin bed of coal might easily be concealed; though on the other hand, it very probably would have been found by owners of the land if any exists. Furthermore, the coal at the last locality described is 30 to 40 feet lower than the first. It is believed that there are two different beds or basins, the latter at least of very limited area. Westward no exposures, excepting sandstone, are seen east of section 10. Rock is abundantly shown where thin beds have broken up leaving detached blocks scattered over the surface.

In Tp. 40 N., R. XXVII W., section 10, northwest quarter, is a seam of coal three feet thick which is exposed in the bed of the creek about 710 feet A. T. This is the only outcrop that could be found. Farther up the creek sandstone and shales are everywhere exposed in the bluffs, but no other rocks, and since exposures are abundant it is concluded that no other strata are associated with them. In section 16, southeast quarter, a drill-hole was put down to a depth of 130 feet but no definite knowledge as to the characer of the beds penetrated could be secured. It is claimed that no coal was met with. The top of the hole is about 800 feet A. T. In the same township, in section 17, northeast quarter, is the following section:

Section IX. Outcrop in Tp. 40 N., R. XXVII W., Sec. 17.

		Feet.
3.	Limestone	1
2.	Shale, black	8
1.	Coal (775 feet A. T.)	2½

The coal is correlated with the Tebo seam which underlies a large area west and north of this, being reached in a large number of shallow wells. It is mined in a number of strip-pits, and is seen outcropping at many places. A bed of sandstone is found in section 5 at an elevation of about 800 feet A. T.

In Tp. 40 N, R. XXVIII W., the Tebo coal bed is exposed in several places. Near Montrose (Tp. 40 N., R. XXVIII W., Sec. 14, NE. qr.) the section of a bed of coal with the associated rocks is about as follows:

Section X. Stripping near Monrose.

		Feet.
5.	Clay and soil, with fragments of limestone	4
4.	Shale, black, fissile	2
3.	Clay, and concretionary limerock	1½
2.	Coal	1⅓
1.	Shale, black (785 feet A. T.)	2

Down the branch, about half a mile to the east, occurs a bed of limestone, with shale and coal beneath. It lies about 20 feet lower than the coal in the last section. Its elevation is nearly the same as that of the Tebo coal at many places east of this and also at a few places to the northwest. The vein in the above section varies somewhat from that of the Tebo coal. Here the coal is only 16 inches thick, while the Tebo seam is about two feet thick. Here it is underlain by black fissile shale with the appearance of another bench of coal beneath, while the Tebo coal occurs in one bed with no black shale beneath it. The indications are that this is a higher bed than the Tebo. One mile and a half north of Montrose the latter vein has been mined and here also the characteristic rocks associated with it are exposed.

SECTIONS IN TOWNSHIP 41 NORTH, RANGES XXVI, XXVII, AND XXVIII WEST.

In Tp. 41 N., R. XXVI W., Sec. 25, several shafts and drill-holes have been put down. One shaft is now being operated by the North Coal Company. The works lie only a few feet east of the limits of the sheet and do not properly belong here. It is 57 feet deep, the top being about 710 feet A. T. The coal is three feet thick.

About half a mile north of the last mentioned locality C. W. Jordan sunk a shaft to the depth of 45 feet. The record, reported, is as follows:

Section XI. Record of Jordan Shaft, No. 3.

		Feet.
4.	Soil and clay (700 feet A. T.)	6
3.	Shale, gray, calcareous and arenaceous	22
2.	Shale, blue, argillacous	14
1.	Coal	2¾

It is stated that the gray shale, No. 3, of this section has the same characteristic appearance as the "limestone" occurring in the Keith and Perry shafts at Deepwater, and at one time was used for curbrock and sidewalks in Clinton, but is better adapted for inside pavement.

About 500 yards south of the north shaft, Mr. Jordan sunk a churn-drill hole to a depth of 48 feet, in which a bed similar to No. 3 was again encountered. West of this point 400 yards, a drill-hole was sunk to the coal without encountering any hard shale whatever, and also in a shaft in the southeast quarter of section 26. In all these shafts and drill-holes, as in Keith and Perry shaft No. 2, there is a stratum of soft shale between the hard arenaceous shale and coal, while in the Keith and Perry shaft No. 1 it lies directly upon the coal, excepting where there is a thin stratum of bituminous clay and shale.

The following is a corrected section given by Broadhead. It is at the Gilkerson ford, on Grand river, in the northwest quarter of section 26.

Section XII. Outcrop at Gilkerson Ford on Grand River.

		Feet
8.	Sandstone, buff, shaly	5
7.	Shale, blue, abounding in lenticular beds of iron carbonate, weathering red, and containing numerous ferns, also Lepidodendron, Lycopodites, Lepidostrobus and Cordaites	2
6.	Coal	⅛
5.	Shale, with clay at top	14⅛
4.	Coal	½
3.	Sandstone, abounding in Stigmaria	3
2.	Shale, contains in its lower parts numerous fossil ferns	21
1.	Coal, in river (663 feet A. T.)	3

About one mile south a churn-drill hole is reported to have passed through three feet of coal at a depth of 72 feet.

The altitude of the top of the hole is about 740 feet A. T. Of the Noble shaft (Sec. 34, NE. ¼ of NW. qr.) no detailed record could be obtained, but it was learned that there were two veins of coal, one eight inches thick, at a depth of 40 feet, and another, three feet thick at a depth of 63 feet. The top of the shaft is 750 feet A. T.

The coal at the Gilkerson ford and that in the North shaft, and the shafts and drill-holes in its vicinity, are correlated with the coal in the Keith and Perry shaft. It is locally known as the Jordan coal. In the vicinity of Deepwater it is the lowest coal bed that is known. The lower Carboniferous rocks outcrop a short distance east of where it is mined and no other coal is known to be exposed within that distance. In the vicinity of the North coal mine it is also the lowest coal in the coal measures, determined by a drill-hole, in the bottom of one of the shafts sunk by Mr. Jordan, which penetrated to the lower Carboniferous rocks. Yet considering the character of the rocks at the base of the coal measures it is unsafe to predict that wherever it is known to exist it is the lowest coal. Many other occurrences of coal at this horizon are described in the report on the adjoining Calhoun sheet.

South and west of the Noble shaft very little rock except sandstone is exposed. A thin bed of coal crops out in a small ravine in the southeast quarter of the southwest quarter of section 33, which is correlated with the upper coal in the Noble shaft. A mile to the west coal is reported in a well 10 feet from the surface. In the northeast quarter of section 23 of this township 23 inches of coal are reported to have been struck in a well at a depth of 35 feet. Less than a half a mile north of this and commencing about 20 feet higher, a shaft was sunk to a depth of 46 feet and a drill-hole in the bottom of the shaft 40 feet deeper, and only a few inches of coal were encountered. About 600 feet north of the shaft is the locality of Broadhead's Jackson mill section. It is as follows:

Section XIII. Outcrop at Jackson Mill.

		Feet.
15.	Sandstone, shaly, containing a few ferns (690 feet A. T.)	4
14.	Coal, rotten	1
13.	Clay	2
12.	Sandstone, hard, white, containing Sigillaria	1½
11.	Sandstone, shaly	3
10.	Shale, clay	16¼
9.	Ironstone, calcareous and pyritiferous	1½
8.	Shale, calcareous, pyritiferous	¾
7.	Clay, blue	1½
6.	Shale, bituminous	1½
5.	Shale, calcareous	1½
4.	Sandstone, hard	4
3.	Coal	1
2.	Shale, underclay	3
1.	Clay, blue, with roots of plants	3

About half a mile east of this locality near the eastern line of the sheet is the Pitcher shaft. The following record was furnished by the owner:

Section XIV. Record of the Pitcher Shaft.

		Feet
5.	Soil and clay (690 feet A. T.)	7
4.	Shale, argillaceous	17
3.	Sandstone, hard	3
2.	Shale, black, and coal	1⅓
1.	Coal	2

The sandstone is probably the northern extension of the hard arenaceous shale in the Keith and Perry and other shafts south of this. Along the creek north of this there have been several shafts operated in a bed of coal two and a half feet thick. It underlies 25 feet of shale, with probably thin sandstones. The most northerly of this group of shafts (Tp. 41 N., R. XXVI W., Sec. 11, SE. qr.) was formerly operated by Mr. Garth of Clinton. It is 28 feet deep and the coal is two feet thick. The top of the shaft is 710 feet A. T.

In the town of Clinton, 200 yards east of the northeastern corner of the Square, coal was struck in a well at a depth of 90 feet. The top of the well is 785 feet A. T. This would place the coal at an elevation of about 695 feet, only 15 feet higher than the coal in the Garth shaft. In the bluffs of Town creek in the western part of Clinton the rocks are well exposed.

They consist, at the top, of thin sandstone and sandy shales with a thin coal bed, which does not seem to be persistent, and which is 30 feet below the top of the hill. Below this, the layers become more shaly and at the base they are mostly argillaceous shales. About 300 feet west of the creek a well was bored in which no coal whatever was encountered, and in which the shales seen in the bluffs east of the drill-hole persisted to the top of the lower Carboniferous rocks. The only place for a coal bed that can be at all correlated with the Jordan coal is in the interval, if there be one, which is doubtful, between the base of the bluff and the base of the alluvium in the drill-hole.

In the northwest quarter of section 9, along the railroad, the bluff from the top down to the railroad level is composed of sandstone and shale. Below the railroad to the level of the floodplain of Grand river the rocks are concealed. On Rose creek south of the township line no other beds than sandstones and shales are exposed.

South of Grand river the same is true. In Tp. 41 N., R. XXVII W., Sec. 13, NE. qr., coal is reported to have been found in a shallow excavation. Nothing could be learned of the rocks immediately associated with it, though sandstone is found in the road 25 feet above the bed and no different rocks are seen in the vicinity. At the site of the old Cook mill, on Grand river (Tp. 41 N., R. XXVII W., Sec. 2, SW. qr.) there is an outcrop of sandstone and shale, with a four-inch bed of coal, the thickness of the whole being about fifteen feet. About one mile south, in the northwest quarter of section 11, at the Mullet coal mine, the following layers are exposed:

Section XV. Record at the Mullet Mine.

		Feet.
8.	Limestone (720 feet A. T.)	1
7.	Shale, argillaceous	2
6.	Shale, dark	2
5.	Limestone, dark	3
4.	Shale, black, with calcareous concretions	1
3.	Shale, black, fissile	1½
2.	Limestone	2
1.	Coal (Tebo)	2½

On the hill to the south the same bed was met with in a well at a depth of 42 feet. The top of the well is about 760 feet A. T. Across the road west of the Mullet coal mine a drill-hole was sunk from the bed of the branch to a depth of 110 feet. Sandstone and shales were the only rocks encountered. One mile southwest of the Mullet mine, in the northwest quarter of section 15, coal has been mined. It was reported to be two feet thick and to be overlaid by black shales and limestone. It is correlated with the Tebo coal at the Mullet mine, although it implies a rise of about 30 feet. There are some other facts which point to this conclusion. It is not at all improbable, however, that this is at an higher horizon than that at the Mullet mine and it may be the same bed that is encountered in the Calvird well half a mile west. The latter lies at an elevation of about 785 feet A. T., and it is overlain by 10 feet of sandstone. On the same property, 1000 feet north, another well was dug. The record reported by the owner of the property is as follows:

Section XVI. Calvird Dug Well.

		Feet.
5.	Sandstone (785 feet A. T.)	10
4.	Clay, blue	5
3.	Limestone, bituminous	2
2.	Shale	1
1.	Coal	2

This does not agree with the Tebo coal in the thickness of the coal bed nor in the character of the associated rocks, but the record was given from memory and some latitude on such points may be allowed. The anticipation of meeting with "big coal" at greater depths results in the lack of full local appreciation of the Tebo coal and other beds lying near the surface. In the northwest corner of section 10, commencing at the top of the hill and running over into section 3 to a stripping in the southwest quarter, the rocks are about as follows :

Section XVII. Outcrop in Tp. 41 N., R. XXV W., Sec. 9, Ne. qr.

		Feet.
13.	Concealed, with fragments of limestone (820 feet A. T.)	20
12.	Limestone, buff	1
11.	Shale and clay, yellowish, calcareous	⅔
10.	Shale, dark	2
9.	Coal (reported)	2
8.	Shale and sandstone	45
7.	Dark streak	1
6.	Concealed (shale)	80
5.	Limestone	1
4.	Shale, agillaceous	1
3.	Shale, black, fissiler	1⅔
2.	Limestone, dark	⅔
1.	Coal (Tebo)	2½

The bottom coal is correlated with the Tebo. The top coal in this section is the first occurrence met with so far, of a coal with which is correlated a bed that underlies a considerable part of the northern third of the sheet and which is now called the Honey Creek coal on account of several outcrops of it occuring on that stream, northwest of Clinton. It was met with at a few localities to the westward. The dark band in the section may be either a thin bed of coal or one of black shale. In the southeast quarter of section 8 of the same township, a well was dug in which coal was struck at a depth of 30 feet. No record could be obtained, but 800 feet northwest of the well and 30 feet below its top a bed of coal, which is correlated with the Tebo seam, has been mined in a strip-pit. About 1800 feet west is the following section:

Section XVIII. Outcrop in Tp. 41 N., R. XXVII W., Sec. 8, Se. qr.

		Feet.
4.	Limestone (760 feet A. T.)	1
3.	Shale, gray, argillaceous	1
2.	Shale, black, fissile	1
1.	Coal	2

The correlation of this with the Tebo coal is justified by the character and thickness of the rocks, though it shows a rise of these beds southward. Its outcrops farther to the

southwest, however, are 20 feet higher than this one. Down the branch from this locality there is no indication of outcrops other than of sandstone and shales. Near the extreme northeastern corner of section 6 there is an outcrop of 12 inches of limestone, underlain by shales and coal, which latter is also correlated with the Tebo bed. One mile south of this locality about 8 inches of coal, overlain by soft shales, are exposed in the bank of the branch. The seam lies at an elevation of about 780 feet. The same coal was encountered at a depth of 44 feet in a well on top of the hill 300 yards west. Here the coal was 10 inches thick. The well was sunk through soft shales from the top down to the coal. Northeast of the well a small hill is capped with limestone which is correlated with the top limestone in section XVIII. In the extreme southwest portion of section 22 the Tebo coal is exposed in a shallow pit where it has been mined. The section is:

Section XIX. Coal Pit northwest of Ladue in Section 22.

		Feet.
5.	Soil (760 feet A. T.)	4
4.	Limestone	2
3.	Shale	1
2.	Shale, black, fissile	1½
1.	Coal	2

In the northern part of the village of Ladue, a drill-hole was sunk to a depth of 90 feet without striking more than a few inches of coal. The top of the drill-hole is about 730 feet A. T. In section 29, southeast quarter, a bed of coal was operated several years ago. It is not now seen, nor the full thickness of the overlying shale, but above this seam is a bed of about three feet of sandstone, which underlies shale. The coal lies 30 feet lower than the Tebo vein at its nearest outcrop, but apart from this the association with sandstone does not permit the correlation of this coal with that bed. It should be assigned to a lower horizon, and probably occupies a small area, since this was the only occurrence of it found. About 500 yards west, a well 40 feet deep did not encounter coal. To the north, three-fourths of a mile, sandy shales are exposed in the ravines, but no coal nor any other rocks similar

to those associated with the Tebo coal are seen. The surface is covered with a deep soil and only shallow wells have been dug. The datum for placing the horizon line of the Tebo coal, where it has been placed in the southwestern corner of this township, is its topographic position at its nearest outcrop.

In Tp. 41 N., R. XXVIII W., Sec. 12, Nw. qr., a 16-inch bed of coal has been mined in a shallow pit. It is overlain by 10 inches of black shale. It does not agree very well with any of the beds previously described, being too high for the Tebo coal and also for that in the Calvird well, and is a little too low for the upper, the Honey Creek coal in section XVIII. In the absence however, of further evidence it is correlated with the last named bed.

A little more than a mile to the southwest an 8-inch bed of coal was struck in a well at a depth of 38 feet, The top of the well is about 830 feet A. T. The bed is probably the same as that in the Calvird well. About 100 rods to the south a thin bed of coal has been mined in the bed of the branch, but the place could not be accurately located. Its horizon is 35 feet below the top of the well and it is doubtless the same coal. No limestone or other hard rocks were encountered in the well nor do any outcrop in the vicinity. Near the northwestern corner of section 14 the following section occurs :

Section XX. Stripping in Tp. 41 N., R. XVIII W., Sec. 14.

		Feet
4.	Limestone (785 feet A. T.)	1
3.	Shale, gray	2
2.	Shale, black, fissile	1¼
1.	Coal	2

The same coal is exposed in a shallow pit in the Ne ¼ of the Se. qr. of section 22 where the character and thickness of the associated rocks are essentially the same. This is correlated with the Tebo coal both on account of its thickness and associated rocks and because it has been traced by frequent outcrops from undoubted exposures of that seam near Montrose. In the Sw. qr. of the Nw. qr. of section 24 a vein of coal about eight inches thick is exposed in the bank of the creek

just south of the wagon road. The coal is overlain by sandy shales and underlain by a few inches of clay resting upon shale.

The Tebo coal is exposed in many places along the south side of Granddaddy creek, and in a few places on the north bank of Deepwater in this township. It everywhere shows its characteristic associations of a solid bed of 15 inches of limestone, blue shale, black shale and coal.

SECTIONS IN TOWNSHIP 42 NORTH, RANGES XXVI, XXVII, AND XXVIII WEST.

In section 24, Nw. qr. (R. XXVI W.) about 150 yards east of the eastern limits of the sheet, a coal bed correlated with the Tebo is operated. Five hundred yards west of this a bed of coal 18 inches thick was encountered in a dug well at a depth of 13 feet. The top of the well is about 785 feet A. T. About 800 feet further west a well was dug to a depth of 36 feet without encountering coal except near the bottom. South of this location near the southeast corner of the southwest quarter of section 23 the Tebo coal is operated in a strip pit at an elevation of about 760 feet A. T. Down the creek from this point the Tebo coal could not be found. Sandstones and shales are everywhere exposed, apparently from the top to the base of the hills.

In the southwest corner of section 26, where the road crosses Town creek, shales and sandstones are the only beds to be seen. The whole hillside is not exposed, but where soft sandstones show prominently it is not probable that a limestone of the resistant character of that overlying the Tebo coal could be hidden. It should be seen either as a ledge or in fragments on the surface. In the northeast quarter of section 27 an excavation made a few years ago disclosed a highly calcareous, fossiliferous, black shale. The bottom of the shale had not been reached at the time of inspection and it could not be definitely determined whether coal had been found or not. There were a few partly filled excavations around the place. The shale lies at an elevation of about 720 feet A. T. Less than 200 feet down the ravine there is an exposure of shales, apparently on the same horizon as the black

shale in the excavation, which are similar in appearance to the shale at the base of the eastern bluff of Town creek west of Clinton. They are not dark nor fossiliferous and seem totally unlike the black fossiliferous shale in the excavation. Half a mile south of the last mentioned place a mine has been opened 300 feet west of the creek (section 34, southeast quarter) in which the coal two feet in thickness is overlain by shale and that again by about two feet of limestone. About 800 feet south of this another mine has been opened on the western side of the branch near the township line. The rocks here exposed are as follows:

Section XXI. Sequence at the Marvin Mine.

		Feet
3.	Limestone, coarse, bluish gray on weathered surface, shows many small crinoid stems, not otherwise highly fossiliferous (top 725 feet A. T.)	2
2.	Shale, argillaceous at top, becoming bituminous and fissile lower down	2
1.	Coal	2

The limestone is made up of two or three layers. Half a mile to the west a limestone with the same structure, bedding and other characteristics lies at an elevation of about 720 feet A. T. Black fissile shale underlies it but no coal is visible and only about one foot of shale. Immediately south of the mine on Town creek near the township line the limestone disappears and does not appear again southward. Across Town creek, 400 feet east of the mine, an excavation in the hillside has exposed 15 feet of sandstone, sand and argillaceous shale, with a thin bed of coal 18 feet above the stream. Probably they are the same as found in the ice-plant wells and represent the northern limit of the Jordan coal basin. The bluffs to the south on the eastern side of the creek are steep and the rocks from top to base are well exposed. They consist entirely of sandstone and shale. The limestone and coal just described certainly do not lie horizontally southward and they undoubtedly do not dip very much or they would have been encountered in one or the other of the wells which have been bored

in the valley south. The only chance for them to extend southward, as has been said before of the Jordan coal, is to lie below the base of the bluff east of the upper well and above the bottom of the alluvium in the well. It is possible that there is not space enough here for the beds. There are no data whatever to determine whether or not these rocks extend eastward, underlying the northern part of the town of Clinton. It is certain, however, that no rocks that can be correlated with these on lithologic grounds can be found east or southeast of this locality. It is impossible to determine whether or not this is the Tebo coal. It differs considerably from that seam in lithological features. The limestone over the latter is a dark, blue, noncrystalline, finely textured rock, weathering smooth, lying in a single bed generally 15 inches thick, while this limestone is coarsely crystalline, weathers into rough blocks, is of a grayish blue color and lies in two or more beds, together making a total thickness of about two feet. It contains a large number of small crinoid stems. Its elevation is the only point in favor of correlating it with the Tebo coal. It lies at the same elevation as at the nearest outcrop of the latter. West of this (northwest corner of section 33), but to the north, the Tebo coal at its nearest outcrop is about 760 feet A. T. No evidence whatever of a southward dip sufficient to bring it to the place occupied by this coal could be found. To correlate the two coals would imply too great a change in lithologic characters of the overlying limestone to be consistent with the remarkably uniform character of the limestone associated with the Tebo coal at the great number of places where it is exposed. If the Tebo coal should change so perceptibly and dip southward sufficiently to be brought to this position there would seem no objection to supposing it to extend further eastward and be equivalent to one of the numerous beds of coal found east and southeast of Clinton. But that it is not the equivalent to one of these beds is made certain by data obtained just east of the area of the Clinton sheet and described in the report on the adjoining Calhoun sheet (see section along Deer creek). In view of these considerations it seems

safe to place the coal at a lower horizon than the Tebo bed and to limit it to a small basin, one of the basin-like deposits characteristic of the lower coal measures.

In the southeast quarter of section 33, Dr. J. H. Britts of Clinton reports a bed of coal, in all respects similar to the Tebo coal, in a well at a depth of 40 feet. The top of the well is about 775 feet A. T. The Tebo coal is mined near the northeast corner of section 32 on Ross creek and is also reached in a well in the northeast corner of section 28 at a depth of 22 feet. The top of the well is 750 feet A. T. It has also been mined in a shallow pit or stripping near the center of the north half of section 22, now operated by shaft near by on the Munson land, at an elevation of about 750 feet A. T.; and is also in a shaft 35 feet deep in the southwest quarter of section 14. The top of the shaft is 805 feet A. T. Along Field creek in this township, there are a large number of exposures of the rocks of the lower coal measures. In section 10 is the following exposure:

Section XXII. Outcrop in Tp. 42 N, R. XXVI, Sec. 10, Nw. qr.

		FEET.
5.	Shale, black, highly calcareous, and very fossiliferous	1
4.	Shale, black, fissile	2
3.	Coal	1
2.	Clay	2
1.	Shale, argillaceous (750 feet A. T.)	

The coal bed underlies a large area north and northeast of this locality everywhere lying about 12 feet above the Tebo seam, and everywhere marked by the same very highly fossiliferous bed of calcareous bituminous shale. The fossils are almost exclusively large individuals of Productus and its spines. About 50 feet above this coal at the locality where the last section was measured a large number of broken fragments of limestone lie over the surface and a few ledges outcrop on the surface. Just across the township line to the north is the Spangler well (Tp. 43 N., R XXVI W., Sec. 34, Sw. qr.). No record could be secured but from a few related facts concerning the well and a dug well near by the section was found to be essentially as follows:

Section XXIII. The Spangler Well.

		Feet.
9.	Undetermined, partly soil (810 feet A. T.)	11
8.	Limestone	4
7.	Shale, black	5
6.	Coal	1
5.	Shale	30
4.	Limestone (?) (calcareous black shale)	1
3.	Coal	1
2.	Indeterminate (shales and clay)	19
1.	Coal	2½

About 600 feet south of the well, on the township line, the following section is exposed:

Section XXIV. Spangler Outcrop.

		Feet.
9.	Limestone, with many fragments of Chonetes (785 feet A. T.)	5
8.	Clay	1
7.	Limestone, blue	1½
6.	Shale and clay	⅔
5.	Limestone	½
4.	Clay	⅛
3.	Shale, black, fissile	¾
2.	Calcareous concretions, highly fossiliferous	1
1.	Coal (reported)	1

In Tp. 42 N., R. XXVI W., Sec. 15, Nw. qr. a coal bed has been mined, which is correlated with the Tebo seam on the basis of the reported thickness of the bed and on the character of the limestone fragments lying around an old opening. Sandstone and shale are the only rocks outcropping along the creek to the west. In sections 20 and 29 the sequence compiled from numerous outcrops is as follows:

Section XXV. Outcrops in Sections 20 and 29.

		Feet
11.	Limestone, shaly	⅛
10.	Shale, black	1
9.	Limestone	1½
8.	Shale, argillaceous	1⅔
7.	Shale, black, fissile	1
6.	Coal (Tebo)	2½
5.	Shale, sandy	7
4.	Shale, argillaceous, dark at bottom	5
3.	Coal	½
2	Sandstone	3
1.	Clay (710 feet A. T.)	2

In No. 7 Broadhead found "grayish, globular concretions and sometimes lenticular beds of dark limerock, which abounded in fossils, including *Solenomya radiata, Nucula ventricosa, Chonetes mesoloba, Ch. verneuiliana, Productus muricatus, P. nebrascensis, Nautilus ferratus, Spirifer lineatus, S. cameratus, Hemipronites crassus, Pleurotomaria sphærulata and Orthoceras cribrosum.*" The fossils lie almost together in the calcareous concretions in the shale. They are not so abundant as in the shale overlying the next coal above this and the individuals are more evenly distributed among several species. No single species greatly predominates in number and size of individuals.

The Tebo coal is exposed in the extreme southeastern part of section 19, and, in the road 300 feet south, 20 to 30 feet of sandstone and shale overlie it. In Tp. 42 N., R. XXVIII W., Sec. 24, Se. qr. a bed of coal was reached by a shaft (Crissman) 18 feet deep. The coal was reported to be 30 inches thick and to be overlain by black shale and that in turn by one foot of limestone. The top of the shaft is about 755 feet A. T. Soil and shales were the only materials encountered above the limestone overlying the coal. In the Young shaft (section 14, Sw. qr.) the rocks are the same and the shaft is as deep as the Crissman. In section 11, a shaft was sunk several years ago but no coal was taken out. It was 35 feet deep. Only 500 yards north of this near the middle of the east line of the northeast quarter of section 11, the Tebo coal is exposed in the bank of the branch. The rocks associated with it are the same as in the last section. In the bed of Honey creek just above the bridge a short distance northwest of this place a limestone is exposed, and again near the mouth of the creek in the southwest quarter of section 10, both of which are correlated with the cap-rock of the Tebo coal.

The Norris shaft is in the northeast corner of section 7. No detailed record could be obtained. The owner of the property stated that two beds of coal were struck, one at a depth of 35 feet and another 10 feet lower. The upper coal is 32 inches thick and the lower 10 inches. The former is over-

lain by black shale and this is turn by limestone. The upper bed is correlated tentatively with the Tebo seam. In section 16, northwest quarter, a bed of coal four feet thick is reported at a depth of 61 feet in a dug and also in a drilled well. Just southeast of the center of section 17, a well was drilled to a depth of 73 feet. No record was obtained but there is a report to the effect that three beds of coal were encountered; one of 14 inches in thickness at a depth of 10 feet, another 36 inches thick at a depth of 40 feet and a third 14 inches thick at a depth of 73 feet. The second bed here is correlated with the Tebo coal. The bottom bed is probably the same as the one in the last well although there is a difference in the reported thicknesses at the two places. The drillers in both cases may have been misled by black shale which they called coal, but even if the two occurrences are as reported and belong to the same bed of coal it is not inconsistent with the character of the lower beds of this formation. Half a mile southeast of this drill-hole is the location of the Hartwell shaft No. 2. The following record was reported:

Section XXVI. Record of Hartwell Shaft.

		Feet.
9.	Soil (730 feet A. T.)	1
8.	Clay, yellow, tough	11
7.	Clay, joint	4
6.	Shale, yellow to bluish at bottom	15
5.	Limestone	½
4.	Clay, hard, bluish	8
3.	Limestone	1½
2.	Shale, black, fissile	2
1.	Coal	2⅝

This is a typical section of the Tebo coal bed and its associated rocks. Towards the south the strata evidently rise. The Tebo seam is next seen at the Marvin school-house (Tp. 41 N., R. XXVII W., Sec. 5, Nw. qr.). It lies here at an elevation of about 740 feet A. T., a rise from the Hartwell shaft of 50 feet. A thin bed of coal outcrops 100 rods down the branch, and also a very thin and non-persistent one in the bluffs of Grand river one and one-half miles north of the school-house. The other beds exposed in the south bluff of Grand river are

sandstones and shales. These are illustrated in section 30 (Tp. 42 N., R. XXVII W.):

Section XXVII. Bluff of Grand River in Section 30.

		Feet.
10.	Shale, sandy	8
9.	Coal	¼
8.	Shale, not persistent	½
7.	Coal	¼
6.	Shale, argillaceous, drab	8
5.	Coal	1½
4.	Shale, sandy	4
3.	Shale, dark, blue	8
2.	Limerock, or calcareous ironstone	⅔
1.	Coal (690 feet A. T.)	1½

The upper two coal layers thin out within 200 feet up and down the river. The strata all rise away from the same point in both directions. The rise is very slight, about three feet in 100. The lowest coal, No. 1 in the section, cannot be correlated with any bed met with so far. The nearest correlation is with the thin bed in the section at Gilkerson ford, but there are a great number of exposures along Grand river between these two points, and it is certain that no persistent bed of coal crops out below the horizon of the Tebo coal. There seems to be a great number of thin beds of limited area, formed originally in slight depressions, such as the section above indicates. It is reported, however, that a bed of coal was mined at one time in the bed of Grand river, near the old Burned bridge (Tp. 41 N., R. XXVI W., Sec. 7, Sw. qr.), but the drill-hole near the Mullet coal mine proves that the bed does not extend far in that direction on that horizon and a drill-hole sunk one mile west of of Hartwell shows that the coal does not extend far northward. The basin-like character of the lower beds of the coal measures is explained by regarding them as belonging to the same horizon on an uneven floor, the deposition progressing in the separate basins at about the same time. The drill-hole west of Hartwell referred to above is in Tp. 42 N., R. XXVIII W., Sec. 18, Nw. qr. It was sunk to a depth of 35 feet. A hard rock was encountered, under which was a bed of black shale and another hard rock a

few feet below. If this report is correct the first hard rock must be placed below the horizon of the Tebo coal unless the latter dips westward from the Hartwell shaft. However this may be, the first hard rock encountered is the only one met with in the drill-hole that can be correlated with any of the rocks associated with the Tebo bed. According to the record the coal is replaced by shale. Four miles south of Hartwell, in section 25, a twelve-inch bed of coal was struck at a depth of 18 feet in a dug well. It was overlain by three inches of "sulphur rock" and that by shale and soil. This section is somewhat like the one on Grand river (section XXVII), half a mile northeast, but supposing this coal is the one in the bed of the river and that the ironstone of the Grand river section is the same as the "sulphur rock" of this section, the bed must rise about 25 feet southward between the two points. On the other hand, this coal bed lies at about the same elevation as the Tebo seam at its nearest outcrop at the Marvin school house, two miles southeast. There is nothing in this vein, however, excepting its elevation that would suggest a correlation with the latter bed. About 1000 feet east of the well loose blocks of limestone much like the cap-rock of the Tebo coal are lying in the road. Above the top of the well southward everything is covered with a deep soil, making it difficult to determine whether it overlies the rocks in the well or not. If it rises very slightly westward it would lie in this concealed interval. There is a little suggestion that such is the case in some exposures on the Schrœler land (Tp. 42 N., R. XXVIII W., Sec. 25, Ne. qr.) A bed of coal has been operated in a shallow pit here and the section measured is as follows:

Section XXVIII. Outcrop on the Schræder Place.

		Feet
5.	Shale, gray, capped by soil	1½
4.	"Sulphur rock"	1¼
3.	Coal, cannel	1
2.	Coal, block	1
1.	Clay	1

The cannel coal is similar to bituminous shale in appearance and is apparently a highly bituminous bed of that kind.

It is stated that there is a very large amount of ash towards the top of the vein but that the lower part near the top of the block coal is of very good quality. About 800 feet west of this locality and commencing 20 feet above it is the Schrœder dug well, in which is reported "granite" at a depth of 12 feet. The "granite" is without much doubt a hard, compact limestone. It lies at about the horizon of the cap-rock of the Tebo coal. The evidence is not sufficient to make the correlation secure. In the northwest corner of section 36 a coal bed is exposed near the top of the hill. Going down the hill to the north the rocks outcropping in succession are as follows, though the exact thicknesses may not be exactly given:

Section XXXIX. Outcrop south of the Schrœder Place.

		Feet.
8.	Concealed, with numerous fragments of limestone	10
7.	Shale, black, with yellowish clay at top	2½
6.	Shale, black, fissile	1¼
5.	Coal	1½
4	Clay and shale	15
3.	Limestone	1
2.	Shale, sandy and argillaceous, and sandstone	30
1.	Concealed	20

The base of the section is at the top of the well near the center of section 25. The coal at the top of this section is mined at numerous places to the west both within and beyond the limits of the area of the sheet. It is thought to be the equivalent of the Honey Creek coal. An outcrop occurring in section 34, southwest quarter, is described below for comparison, although the locality lies outside the limits of the sheet:

Section XXX. Outcrop in Section 34.

		Feet.
4.	Limestone (860 feet A. T.)	1
3.	Clay	1
2.	Shale, black, fissile	5
1.	Coal	1½

Data for correlating this with the coal in the preceding section are not numerous. There is some difference in the elevation of the coal at the two places but the associated rocks are about the same. In Tp. 42 N., R. XXVIII W., Sec. 22,

Ne. qr. a well was dug to a depth of 55 feet, in which a coal bed 18 inches thick was encountered, according to a report of the owner; but the exact depth at which the coal was reached could not be given. On the south side of section 15, just outside the limits of the sheet, on the Elder land, a well was dug in which the following rocks were passed through:

Section XXXI. Well on Elder Place.

		Feet.
3.	Soil and shale (715 feet A. T.)	30
2.	Shale, blue	20
1.	Coal	2½

At the house on the west side of the road, 500 yards west and also about the same distance south, wells were dug striking coal at about the same horizon.

Along the north bluffs of Grand river near the western limit of the sheet and beyond, especially in the vicinity of Urich, half a mile from where Grand river enters the area, sandstone and shales are the only rocks exposed. A well sunk at the Flouring mill in Urich to a depth of 42 feet passed through sandy and argillaceous shales from the top to the bottom. The top of the well is about 720 feet A. T. From the position of the strata of the upper coal measures cropping out north of Hartwell it seems quite evident that the sandstones and shales underlie them. The latter are placed in the lower coal measures, but the Tebo coal and its associated beds which, over the greater part of the sheet are the most persistent features of the formation, were not seen west of Hartwell, on either side of Grand river, unless the "granite" in the Schrœder well belongs with it. From a consideration of the facts described in the preceding pages it seems improbable that the Tebo coal should underlie the coal in the Elder well. Even if the hard rock in the Schrœder well should not prove to be the cap rock of the Tebo coal there is very little chance for it to get through the northeast corner of section 25, and adjacent parts of adjoining sections. If it lies above the Schrœder well it would most likely have been found in the steep ravines southeast of the well. If it does not lie above the well it must come in between

the bottom of the well in the southern part of section 25 and the top of the outcrop on the bank and bluff of Grand river in section 30 of the next township east. This seems improbable, since it would have been cut by the branch running northward through the latter section. Sandstones and shales are well exposed along it but no limestone so far as observations extend.

If the Tebo coal lies above the top of the Elder well a northward dip is necessary to bring it beneath the bottom of the well at the Urich mill. There are some workable coal beds outcropping west and southwest of the Elder well but they were not visited. Work in this direction will probably solve the problem of the westward extension of the Tebo seam of coal. Recent drilling at Creighton at the extreme western edge of the county and about five miles west of Ulrich, fails to show any beds which can be correlated with the Tebo coal.

SECTIONS IN TOWNSHIP 43 NORTH, RANGES XXVI, XXVII AND XXVIII WEST.

In the southeastern portion of that part of township 43 north, range XXVI west, which lies within the area of the sheet, limestones are abundantly exposed in single ledges and in fragments which lie over the slopes of the hills. In the southwest quarter of section 35 the rocks exposed are:

Section XXXII. Outcrop in Section 35.

		Feet.
8.	Concealed, with fragments of limestone (760 feet A. T.	20
7.	Limestone	1½
6.	Clay	½
5.	Limestone	3
4.	Shale and clay, dark	1
3.	Limestone, shelly	1
2.	Shale, black, fissile	1
1.	Limestone, dark, in bed of branch	1½

Up the branch, eastward, the rocks rise with the bed of the creek and where the road crosses it near the southeastern corner of the section the top limestone lies in the channel. This section is correlated with the rocks exposed near the Spangler well, a mile to the west. On the Jones farm (Tp. 43 N., R. XXVI W., Sec. 27 Sw. qr.), coal has been worked, in the vicinity of which are exposed:

Section XXXIII. Exposure near the Jones Place.

		Feet.
6.	Soil, containing small fragrants of limestone (925 feet A. T.)	2
5.	Shale, black, fissile	4½
4.	Coal	1½
3.	Concealed	3
2.	Limestone, arenaceous	1
1.	Shale, with thin sandstone	6

The coal is 40 feet higher than the upper coal in the Spangler well. There are no data showing a rise of the latter seam northward. The further fact that the sections are different justifies a reference of this seam to a higher stratigraphic position than the Spangler seam. Not far above the coal is a bed of sandstone; and another bed of coal is reported still higher, but farther northwestward on the same property. A bed of limestone caps the hill in the extreme southeastern corner of section 28 about 40 feet higher than the coal at the Jones place.

In a small branch in the northwest portion of section 28 and adjacent portions of 29 a coal bed occurs in two or three places. Beneath it are shales very much like those occurring beneath the coal at the Jones farm. Limestones are exposed in many places in section 26 and the northern part of 27, but the details were not made out. At Huntingdale the rocks exposed from the top of the hill westward to the creek one and one-half miles west of the town, as nearly as could be determined, are as follows:

Section XXXIV. Outcrops at Huntingdale.

		Feet.
8.	Limestone (855 feet A. T.)	2
7.	Concealed (probably mostly shales and sandstones)	40
6.	Sandstone and sandy shale	60
5.	Limestone, highly fossiliferous, containing *Chonetes mesoloba* in great abundance, with large numbers of *Productus muricatus*.	1½
4.	Shale, black, fissile.	2
3.	Coal	1
2.	Clay	2
1.	Limestone.	3

The horizon of the Jones coal is near the base of No. 7 of this section. On the ground there is not much evidence that it occurs here though the soil is a little darker than above or

below it. The limestone, No. 8, is correlated with the limestone in the southeastern corner of section 28. The beds below No. 5, of this section, are thought to be closely associated with the rocks exposed near the Spangler well and with those overlying the upper coal in the well. This correlation is made because this limestone appears to be the first limestone above the Tebo coal and its associated limestone. The limestones capping the Spangler well are certainly the first above it at that place. The reason for thinking this the first above the Tebo coal here is that no others were found outcropping down the creek between this and where the latter coal appears. In the record of the Spangler well a limestone is reported just above the middle coal but the outcrops of that bed in many places near the well and north and northeast of it show only a calcareous fossiliferous shale overlying it. Another reason for the correlation is based upon the fact that on Tebo creek east and northeast of the northern part of this sheet the *Chonetes mesoloba* and *Productus muricatus* fauna of section XXIV occurs in a thin limestone associated with other beds above and below it, which resemble those associated with the Spangler coal. It is underlain by a few inches of bituminous clay and that in turn by a bed of marly limestone, very much like the bed at the base of this section. It has been clearly demonstrated that the limestones on Tebo creek carrying this fauna are the first beds of the kind above the cap-rock of the Tebo coal and the occurrence of the same fauna in somewhat similar associations at Huntingdale is considered good evidence of a similar relation of these beds to the same coal.

Where the road turns northward (Tp. 43 N., R. XXVII W., Sec. 25, Sw. qr.) a limestone is exposed, principally by fragments, which belongs in the sequence exposed in the last mentioned section (XXIV), though its place is below any of the beds there seen. Going down the hillside 600 feet beyond, a coal bed is exposed which is interpreted to be the Honey creek coal. Less than half a mile north of this an outcrop in the bank of the creek shows a more complete section of the successive beds supposed to be the same.

Section XXXV. Outcrops in Section 25.

		Feet.
10.	Limestone (740 feet A. T.)	1½
9.	Clay	2½
8.	Limestone	1
7.	Clay	½
6.	Shale, black	2
5.	Shale, sandy, light colored	2
4.	Coal	1¼
3.	Shale, light colored	7
2.	Calcareous concretions	½
1.	Shale, dark	8½

According to interpretions believed to be correct, the fossiliferous bed shown in the Huntingdale section belongs a few feet above the top of this section. A thin bed of coal outcrops in a ravine in the southern part of section 26 of the same township, which is probably the equivalent of No. 3 of the Huntingdale section. It lies probably 15 feet above the principal coal bed of the section, and the absence of the latter in the Spangler and Huntingdale sections is explained by the fact that it lies beneath all the rocks there seen. It outcrops in section 26, where its relation to No. 3 of the Huntingdale section was made out. Its thickness was not determined, though it is probably not more than 12 to 15 inches. Overlying this succession of rocks, along Honey creek, there are no continuous exposures for a thickness of 60 feet. The interval is probably made up of soft shales corresponding to the shales in the in the Huntingdale section. In Tp. 43 N, R. XXVI W., Sec. 1, Sw. qr. is a 12-inch bed of coal lying at an elevation of about 790 feet A. T. It is overlain by a bed of black, fissile shale, and that in turn by one to two feet of limestone. It is probably the equivalent of the coal at the Jones place.

Between Honey and Big creeks the tops of the hills are capped with limestone, but there are no exposures where the details are well shown. In Tp. 43 N., R. XXVII W., Sec. 27, Nw. qr. a thin bed of coal is reported as occurring in a well 30 feet below the top of the hill. Southeast of the center of section 34 a well was sunk in which a bed of coal said to be one

and one-half feet thick was struck at a depth of 18 feet, the elevation being 740 feet A. T. No other exposures were recorded east of Big creek. The first one to be noted west of it is in the channel at the ford in section 29, northwest quarter. These, together with those exposed in the eastern part of the adjacent section on the west, are as follows:

Section XXXVI. Exposure on Big Creek.

		Feet.
8.	Shale, sandy (740 feet A T.)	20
7.	Coal	1¼
6.	Clay	4
5.	Limestone	1¼
4.	Shale	1
3.	Concealed	12
2.	Limestone	1½
1.	Shale, black, fissile (exposed to water in creek)	4

This section is made up from outcroppings at three localities all within a short distance of one another. The concealed space is made up from comparing the elevations of the various outcrops and assuming that within the distances given the rocks are nearly horizontal. At the middle of the south line of section 28, as the road turns south, half a mile southeast of the last mentioned locality, a bed of coal is exposed in a shallow pit. The section is:

Section XXXVII. Coal Pit in Section 28.

		Feet.
3.	Limestone	1
2.	Shale, with black fissile shale at top	9
1.	Coal (720 feet A. T.)	1

The limestone in this section is thought to be the same bed as No. 2 of the preceding section. If so it shows a rise toward the south of as much as 20 feet between the two localities. The shales and thin sandstones at the top of section XXVIII overlie the limestones here, but the rocks for a few feet immediately above this limestone are not well exposed. Southward there are many outcrops of limestone in the road. On the township line the lower limestone exposed lies about 30 feet above the foodplain of Big creek. South of this a few low mounds rising above the general level of the surrounding

country are capped with limestone. The record of the Norris shaft shows a bed of limestone, but it has not been correlated with the cap-rock of the Tebo coal. The details of the relation of the limestone to the coal bed could not be obtained, and the further fact that the elevation of the top of the shaft is not accurately determined makes any correlation doubtful. However, it seems probable that the lower coal bed and the limestone overlying it in the last section lie at a higher horizon than the top of the Norris shaft,

A bed of coal was struck in a well in a ravine near the middle of the west line of the northwest quarter of section 32. Several feet of sandy shale were passed through above the seam, but the rocks immediately overlying it were not determined. West of this, and at a considerably higher horizon at least one more bed of coal occurs. The associated rocks consist of shales and limestones, with the latter becoming important near the tops of the hills. In Tp. 43 N., R. XXVIII W., Sec. 36, Nw. qr., a bed of coal was mined several years ago, and was reported to be 18 inches thick, and to be overlain by black fissile shale. No ledge of limestone is recorded, but it is found capping the neighboring hills. Other outcrops are not recorded in this part of the sheet excepting the beds of sandstone and shale in the vicinity of Urich as already described.

FLORA OF THE COAL MEASURES.

An unique and extensive coal flora occurs in Henry county. The plants are chiefly described by Lesquereaux. The complete list so far as identified is given below. The types are chiefly in the collection of Dr. J. H. Britts, of Clinton, who discovered this rich plant bed. The plants are found in the shales immediately overlying the Jordan coal at a locality one-half mile east of Deepwater, and at the Pitcher, Owen and McLeod mines southeast of Clinton.

Taonurus colletti, Lesqx.
Annularia angustifolia, Lesqx.
Annularia longifolia, Brgt.
Annularia sphenophyloides, Lenk. and Gutb.
Asterophyllites fasciculatus, Lesqx.

Asterophyllites rigidus, Brgt.
Calamites cistii, Brgt.
Calamites suckowii, Brgt
Sphenophyllum erosum, Ll. and Hutt.
Sphenophyllum filiculme, Lesqx.
Sphenophyllum longifolium, Germ.
Sphenophyllum oblongifolium, Germ.
Sphenophyllum schlotheimi, Brgt.
Neuropteris angustifolum, Brgt.
Neuropteris cordata, Brgt.
Neuropteris dilotata, Ll. and Hutt.
Neuropteris flexuosa, Lesqx.
Neuropteris hirsuta, Lesqx.
Neuropteris loshi, Brgt.
Neuropteris missouriensis, Lesqx.
Neuropteris rarinervis, Beeby.
Neuropteris tenuifolia, Brgt.
Odontopteris heterophylla, Lesqx.
Odontopteris sphenopteroides, Lesqx.
Odontopteris subcrenulata, Lesqx.
Dictyopteris obliqua, Beeby.
Alethopteris ambigua, Lesq.
Alethopteris lonchitica, Schloth.
Alethopteris serlii, Brgt.
Callipteridium membranaceum, Lesqx.
Callipteridium owenii, Lesqx.
Callipteridium sullivantii, Lesqx.
Pseudopecopteris acuta, Brgt.
Pseudopecopteris irregularis, St.
Pseudopecopteris macilenta Ll. and Hutt.
Pseudopecopteris nummularia, Gutbier.
Pseudopecopteris obtusiloba, Brgt.
Pseudopecopteris sillimanni, Brgt.
Pecopteris arborescens, Brgt.
Pecopteris clintoni, Lesqx.
Pecopteris cristata, Getb.
Pecopteris dentata, Brgt.
Pecopteris erosa, Gutb.
Pecopteris pennæformis, Brgt.
Pecopteris vestita, Lesqx.
Sphenopteris brittsi, Lesqx.
Sphenopteris chærophyloides, St.
Sphenopteris cristata, Brgt.
Sphenopteris dubuissoni, Brgt.
Sphenopteris furcata, Brgt.
Sphenopteris gravenhorsti, Brgt.
Sphenopteris mixta, Schp.
Sphenopteris spinosa, Gopp.
Sphenopteris splendens, Lesqx.
Sphenopteris tridactylites, Brgt.
Eremopteris missouriensis, Lesqx.
Rhacophyllum adnascens, Ll. and Hutt.

Rhacophyllum arborescens, Lesqx.
Rhacophyllum filiciforme, Schp.
Rhacophyllum fimbriatum, Lesqx.
Rhacophyllum hamulosum, Lesqx.
Rhacophyllum hirsutum, Lesqx
Rhacophyllum lactuca, St.
Rhacophyllum membranaceum, Lesqx.
Rhacophyllum spinosum, Lesqx.
Sorocladus ophioglossoides, Lesqx.
Lepidodendron brittsi, Lesqx.
Lepidodendron cyclostigma, Lesqx.
Lepidodendron lanceolatum, Lesqx.
Lepidodendron marginatum, Lesqx.
Lepidodendron sternbergi, Ll. and Hutt.
Lepidophloios dilatatus, Lesqx.
Lepidophloios sigillaroides, Lesqx.
Lepidophyllum magum, Brgt.
Lepidophyllum minutum, Lesqx.
Lepidostrobus goldenbergii, Schp.
Sigillaria fissa, Lesqx.
Sigillaria menardi, Lesqx.
Sigillaria veniformis, Brgt.
Sigillaria sculpta, Lesqx.
Sigillaria spinulosa, Genn.
Pinnularia capillaceæ, Lesqx.
Cordianthus dichotomus, Lesqx.
Cordianthus gemmifer, Lesqx.
Cordaites communis, Lesqx.
Cordaites diversifolius, Lesqx.
Lepidoxylon anomalum, Lesqx.

Pleistocene and Recent Deposits.

The Clinton area lies south of the southern limit of the glacial drift. No foreign bowlders nor any material at all similar to the drift clays and sands of northern Missouri occur. Probably the only deposit occurring in the area that belongs to either of these classes is the alluvium of the stream valleys. At some localities on lowland near the larger streams there is a peculiar, though rather thin, deposit, the nature and origin of which has not been fully determined. It may be the equivalent of the loess of the Missouri river counties, or careful examination may show it to be only a phase of the residuary soils of the area.

The alluvium of the river and creek bottoms underlies rather a large portion of the areal extent of the county. In

many places there are indications of two phases of this deposit; an older one including much the larger part of the total area, made up of yellowish to drab clay with little or no gravel, or other coarse material, and a later phase made up of clay, sand and small gravel lying in a narrow strip along the present channels of the streams. The surface underlain by the deposit of the first phase is generally bare of timber, is poorly drained and has numerous large ponds and marshes scattered over it. It supports a growth of a coarse grass. The surface underlain by the deposits of the other phase is generally covered with timber, and when cleared it is sufficiently well drained to produce good crops.

GEOLOGICAL STRUCTURE.

GENERAL CROSS-SECTIONS.

The stratigraphic relations of the beds are shown in the cross-sections on plate III. The location of each section is shown on the topographic map. Section 1 shows the relations of the strata across the northern part of the sheet, and also the persistence of the different beds and the general northwestward dip. Section 2 shows the relation of the beds across the central part of the area including some beds beneath the horizon of the Tebo coal. Section 3 extends across the southern part of the sheet.

UNCONFORMITIES.

No plane of unconformity appears to be exposed within the area excepting that of the alluvium on the older rocks. From observations made in the districts adjoining, it is known that the coal measures lie unconformably on the lower Carboniferous. The line has been exposed by Marshall creek, but is now covered again by alluvium.

COAL DEPOSITS.

The coal deposits of the Clinton sheet are important, though on account of the lack of proper transportation facilities they have never been mined to a great extent. Small mines have been opened in a great number of places, but at comparatively few of these has there been any mining done, excepting what was necessary to supply the local demand for fuel. The Missouri, Kansas and Texas railroad does not cross either of the coal fields of the Clinton area, but runs parallel to both belts, and lies on barren ground between the two. The Kansas City, Clinton and Springfield railroad crosses one of the fields, and reaches the other only near the border of the area. The Kansas City, Osceola and Southern railroad crosses only one of them, but taps the other just beyond the eastern border of the district. There was no mining for shipment, therefore, until after the building of the two last mentioned roads. This was about ten years ago. Before that date there was no mining on a commercial scale within the Clinton area. Small mines, however, have been in operation ever since the first settlement of the country.

GEOGRAPHIC DISTRIBUTION OF THE DEPOSITS.

The workable coal deposits of the Clinton sheet underlie two separate areas, and include three different beds of coal, in two of which are practically all the mines, the third one being too thin to be worked at a profit, excepting under the most favorable circumstances. One of these areas, of which Deepwater is the center, lies in the southeastern corner of the sheet. It includes the Jordan coal bed. Only a small portion of the total area underlain by this coal bed lies within the limits of the Clinton sheet, the rest or nearly all the rest, lying within the Calhoun sheet. The western limit of this area enters the sheet from the south, near Marshall creek, and runs thence northeastwardly, in an irregular line, passing across the eastern border about on the latitude of Clinton. The coal bed may extend west of this line but the best evidence indicates that if

it does, it becomes very much thinner, too thin, in fact, to be worked profitably.

The other area extends, in a belt several miles in width, northeastward and southwestward across the central and northwestern parts of the sheet. Its eastern boundary enters the southern border of the Clinton area near Montrose. It runs thence northeastwardly across Grand river, southwest of Clinton, and the eastern border of the area about two miles north of the same place. This line is shown, in great detail, on the accompanying folio map as the outcrop line of the Tebo coal bed. The western border of this belt crosses the western line of the district about three miles south of where Grand river crosses the same line. It trends northeastward approximately parallel to the eastern border.

The coal beds which are workable within this belt are the Tebo and Honey creek beds. The upper one, the Honey Creek bed, is known to occur west of the Clinton area, but between the western limit of the belt as indicated above and the western line of the sheet it does not occur in such a position as to be available for mining. It apparently dips toward the northwest, and over the northwestern part of the area seems to be replaced by sandstone. It is believed to appear also in the extreme western part of the county and in the eastern part of Cass. This may be due to a rise of the beds, or to a reappearance beyond a barren area of sandstone. The lower or Tebo bed appears to thin out near the western border of the belt described above. A careful consideration of outcrops and an examination of well-borings fail to show its existence west of the line.

VERTICAL DISTRIBUTION OF THE COAL BEDS.

The coal bed mined in the southeastern area, the Jordan bed, is geologically the lowest seam within the limits of the region. It lies very near the base of the coal measures. Its elevation above the bottom of the formation varies slightly in different places on account of the uneveness of both the old surface upon which the coal measures were laid down, and the

coal bed itself. The rocks associated with it dip westward and extend under the central area, but the results of the examination of outcrops and drill-hole records show that the coal thins out near the western line of the field already described. The Jordan coal bed occupies a basin lying in the southeastern corner of the Clinton and the southwestern part of the Calhoun sheet and extends a few miles south of the southern limits of both districts. The Jordan coal is the only workable bed in the southeastern area. A thin bed (8 inches thick) overlies it in most of the area, but it is too thin to pay for mining.

The next higher bed, above the Jordan seam, which is of workable thickness is the Tebo bed. The area underlain by it has already been described. Its thickness and character are uniform over the whole area. It is persistent excepting when cut out by streams. The thickness of the Tebo coal is uniformly about 30 inches. Above the Tebo coal lies the Honey Creek vein. Like the former it is persistent in character and thickness over the whole area of its occurrence. It is usually 12 to 14 inches in thickness and, of course, is not workable excepting under the most favorable circumstances. It is mined in a few places, on the outcrop, for fuel to supply local demands. It is nowhere mined excepting in shallow open pits and is not mined for shipment.

The vertical distance between the horizons of the Jordan and Tebo coals varies considerably but the average is not far from 100 feet. That between the Tebo and Honey Creek coals is more constant though there is a slight yet gradual change from north to south. The average is about 60 feet.

Mines in the Jordan Coal Bed.

This bed of coal was named for the Jordan mines when the coal was first operated. Mining began with the building of the Kansas City, Clinton and Springfield railroad about ten years ago. Mining in the same bed of coal was begun in the vicinity of Brownington a few years earlier.

One of the most important mines within the Clinton area is that operated by the Central coal company which is located about half a mile east of Deepwater. The coal is reached by a shaft which is located at the eastern edge of the sheet, part of the workings, at least, lying outside of the Clinton area. The shaft is a double hoist, well equipped with machinery for handling the coal and for ventilating the mine. It is 60 feet deep and is connected with the Kansas City, Clinton and Springfield railroad by a spur about one mile in length. Employment is furnished to 100 men and boys. The mine is operated continuously throughout the year. It is the best equipped and most valuable mining property within the area. The coal is shipped to Kansas City and various points on the Kansas City, Clinton and Springfield railroad. It is a good steam-producing coal and much of it is used for that purpose. It contains thin plates of pyrite and gypsum between the joints, but otherwise it is free from impurities. It is of a brilliant black color and hard enough to stand transportation fairly well. The details of the bed are shown in figure 5.

	Inches.
Shale, arenaceous, hard (roof) fissile	18
Shale, dark drab	12
Sandstone (occasionally)	8
Coal	20
Shale, pyritiferous, with coal	2
Coal	24
Shale, with coal	8
Clay shale	24

Figure 5. Section of Coal Bed at Central Shaft.

An analysis of this coal, made by J. D. Robertson, shows:

	Per Cent.
Moisture	5.12
Volatile matter	38.58
Fixed carbon	43.59
Ash	12 71

The same coal bed is worked at the Noble shaft (Tp. 41 N., R. XXVI W., Sec. 34, Nw. qr.) This mine, however, is not connected with the railroad, and mining is carried on for local consumption only. The greater part of the output is hauled to Clinton and used for domestic and steam purposes.

It is worked generally only through the winter months. It is the only mine that is worked to any extent, that supplies fuel to a large area of well occupied territory west of it, and enjoys a good trade. Within the last few years coal has almost entirely replaced wood as a domestic fuel even among the farmers and this has greatly increased the amount consumed, making the local market an important one. This is supplied, however, principally from mines located northeast of Deepwater and east of the area of the Clinton sheet. The Jordan coal was operated several years ago in a series of shafts along the creek from the Garth shaft near Clinton to Grand river. These mines have been abandoned.

Operations in the Tebo Coal Bed.

The Tebo coal bed is the most extensive in geographic distribution, of any of the coal beds within the area of the sheet. Over a large part of the district it lies only a few feet beneath the surface. Owing to the very resistant bed of limestone associated with it, it is exposed in a great number of places, many of which have been already described. To this fact is due the opening of the great number of shallow pits. Its outcrop is so easily recognized by its capping limestone that no skill is required in locating it. On many farms along its outcrop are pits from which is mined fuel for local use. The detailed sections of the coal bed and its associated rocks are about the same everywhere that the outcrops occur. The latter are located on the map and most of them have been described in the preceding pages. It can be seen from the descriptions that they are all very much alike.

At the time of examination only three small pits were being operated within the area. These were the Montrose, the Mullett and the Marlowe. The one at Montrose has been described, and it has already been shown that there is some uncertainty in correlating it with the Tebo coal. The section of the Mullet has also been given. The Marlowe mine is located

in Tp. 42 N., R. XXVI W., Sec. 19, Se. qr. The details are as follows:

		Feet.
5.	Limestone	1
4.	Clay and black fissile shale	3
3.	Limestone (not persistent)	1/3
2.	Coal, with numerous lenticular masses of pyrite and shale	2 2/3
1.	Clay (exposed)	2

In general, within the area of the Clinton sheet the Tebo coal bed averages about two and a half feet in thickness. It has no persistent shale-parting separating it into benches, but lenticular masses of pyritiferous shale are distributed irregularly through the bed. They are in such abundance, in many places, that unless they are removed before shipment they seriously injure the sale of the coal.

Two shafts have been opened in the coal within the area of the sheet; with both the intention was to operate on an extensive scale. They are both near Hartwell, and are connected with the Kansas City, Clinton and Springfield railroad. Heretofore they have not been operated extensively and there have been no facilities for handling large quantities of coal. Both shafts are shallow, less than 40 feet in depth, and in each the coal was hoisted by horse-power. At the present time one of these shafts is being operated in a very small way, the other having been abandoned some years ago. The reasons given for the abandonment were that the expense incurred in rendering the coal marketable was too great to warrant mining. The details of the seam are given above (figure 6).

Figure 6. Details of Coal-bed at Hartwell Mine.

The same bed of coal is operated at a number of places in the vicinity of Lewis station, about seven miles northeast of Clinton.

An analysis of the coal from the Hartwell mine, by Robertson, gave the following results:

	Per cent.
Moisture	5.76
Volatile matter	39.79
Fixed carbon	43.03
Ash	11.42

Chauvenet made an analysis of the same coal from the Britts mine, five miles west of Clinton. The results are:

	Top.	Middle.
Water	2.89	3 88
Volatile matter	28.55	43.67
Fixed carbon	50 71	43.42
Ash	17.85	9 03

The Tebo coal bed underlies an area within the Clinton sheet of about 80 square miles. Assuming its thickness to average only 30 inches, and allowing 1000 tons of coal for each foot of thickness over each acre in extent the total tonnage amounts to 128,000,000 tons of workable coal. Allowing 30 per cent for waste there remains 85,300,000 tons of available coal. The amount mined up to date is so small comparatively, that it need not be considered.

The Honey Creek Bed.

The seam which has been called the Honey Creek coal is not operated at any point at present and will probably never be of very much economic importance. It has been opened at several places, but is worked only during the winter months and then only for local consumption. It has been opened at the Spangler place, at the middle of the south line of section 29 (Tp. 43 N., R. XXVII W.), in the northwest corner of section 10, and in the same portion of section 36 of the next township to the northwest. Its quality seems to be good, but the thickness of the bed (about one foot) is not great enough to encourage working.

Other Coal Beds.

A thin bed of coal lies between this one and the Tebo bed in the northern part of the sheet, but it never reaches more than a foot in thickness, and rarely that much.

The Jones coal is also too thin to become of any importance to the industries of the area. It may be mined for fuel and used locally, but until the cost of mining thin beds is greatly reduced or the price of coal becomes much higher it will be of little value.

Between the lowest outcrops in the west part of the area and the base of the coal measures beneath them little is known. A few drill-holes have been sunk, all of which have been described in the preceding pages. This is true of the western part of the area only. Over the eastern part, the lower Carboniferous rocks have been reached at a number of places. The question of the occurrence of deep coal beds below the Tebo seam and below the bottom of the drill-holes in the western part of the area is an important one, but one which cannot be definitely decided from the data at hand. The submergence inaugurating the deposition in the coal measures was a gradual one and the deposits at the base of the formation are everywhere shore-line deposits. There were estuaries of shallow quiet waters and islands and peninsulas on which the waves beat and prevented the accumulation of deposits of any kind for considerable periods. The basins may have become marshes and peat swamps of small area which afterward were converted into coal beds. They were not continuous over wide areas nor were the depostits of even thickness throughout the extent of the marsh. Deposits of this character are known to have been formed in the eastern part of the Clinton sheet and further eastward where there are numerous small basins of coal which are not connected with one another and which were accumulated in the shallow estuaries of the old Carboniferous shore. There is no evidence at hand that these conditions existed only in the eastern part of the area. Since, from the known wide extent of the unconformity it must exist under the area of the western part of the sheet, there is nothing in the nature of the case so far as known to hinder the occurrence of coal beds of small areal extent under this part of the field as well.

These are, however, only the possibilities of their existence. The fact of their existence in workable quantities can be determined only by careful prospecting. Assuming that they do exist under the conditions stated there still remains the question of their availability, and whether the expense of the prospecting necessary to find and follow such deposits would warrant their operation.

CLAY DEPOSITS.

(By H. A. Wheeler.)

The clay deposits of the area were especially investigated from a commercial and economic point of view. Among the important industries of Henry county the mining of clays and their manufacture into stoneware, brick and tile take a prominent position. A considerable part of the industry is located in the western half of the county in the Clinton area. The clays of Henry county may be classified under the heads of stoneware or potters' clay, fireclay, shale, residuary clay and gumbo.

STONEWARE CLAYS.

Under this head are several pits and outcrops. An exposure in a cut on the Kansas City, Clinton and Springfield railroad one-half mile south of Clinton shows:

Section in Railroad Cut South of Clinton.

		Feet.
5.	Soil	½
4.	Sandstone	2
3.	Shale, yellow, highly lamellar, soft and plastic, with thin limonite layer at the base	1
2.	Clay, blue to gray (potters')	5
1.	Shale, sandy, brown, very ferruginous	2

The bed of potters' clay in this section was used at the Gulf pottery in Clinton and found very good for this purpose. The Frowein pit is on the Field creek road one mile northwest of the town. It was opened in 1890 and furnished most of the clay used in the local potteries. The side of the excavation here shows:

Section at Frowein Pit.

		Feet.
5.	Shale, sandy, light gray	4
4.	Shale, sandy, gray	1
3.	Shale, yellow, sandy	1
2.	Sandstone, soft, gray, ferruginous	1
1.	Shale, sandy, dark gray, somewhat iron stained	5

The bottom bed exposed is the one used in the potteries. It shows the following characteristics: Color variable, very light gray to olive green to blue to black, very much stained yellow to brown by iron. Texture laminated, fine-grained, rather soft, and not uniform. Taste gritty and fat. Slacked slowly but completely into coarse granules. Pyrite was not visible, but a few very small mica flakes were present. When ground to 20-mesh and mixed with 21.5 per cent of water it made a plastic paste that shrunk 7.7 per cent on drying and 4.0 per cent when vitrified, giving a total shrinkage of 11.7 per cent. Briquettes of the air-dried mud gave an average tensile strength of 143, and a maximum of 164 pounds to the square inch. Incipient vitrification occurred at 1,950°F., and viscous above 2,350°. It rapidly dried and heated without cracking, and burned to a brown compact, tough body, when vitrified.

An analysis gave the following results:

	Per Cent.
Silica	64.97
Alumina	22.64
Water	5 50
Sesquioxide of iron	3.28
Lime	0.61
Magnesia	0.80
Alkalies	2 74
Total	100 54
Total fluxing impurities	7.43
Specific gravity	2.37

About four miles northwest of Clinton (Tp. 42 N., R. XXVI W., Sec. 29, Nw. qr.) on Field creek, Ladd found the following section:

Section on Field Creek.

		Feet.
13.	Limerock, hydraulic	1½
12.	Fireclay, calcareous	2½
11.	Shale, black, with concretions	1
10.	Shale, black, with fossils	6
9.	Coal	8
8.	Fireclay, impure (1 foot ferruginous)	3½
7.	Coal	1
6.	Fireclay	1
5.	Shale, black, soft, contains alum (taste)	5
4.	Coal	1½
3.	Fireclay, impure, sandy	8
2.	Sandstone	1½
1.	Clay, potters' (sample tested)	4

A sample of the potters' clay that was collected had the following characteristics: Color light gray to bluish black, with yellow to brown iron stains. Texture soft, laminated, very fine-grained and uniform. Taste rather fat and decidedly of alum. Slacked very slowly and imperfectly into coarse granules. Pyrite was present as small seams and crystals. When ground to 20-mesh and mixed with 18.5 per cent of water it made a decidedly plastic paste that shrunk 6.5 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 10.5 per cent. Briquettes of the air-dried mud gave an average tensile strength of 140, and a maximum of 163 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 2,000° and viscous above 2,200°. It dried rapidly and heated without checking and burned to a red to brown, compact, tough body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	55.89
Alumina	25.79
Water	8 60
Sesquioxide of iron	4.83
Lime	0.58
Magnesia	0.81
Alkalies	3.89
To'al	99 84
Total fluxing impurities	9.56
Specific gravity	2 33

On the Grant farm, three and one-half miles north of Clinton, the following section is to be seen on the bank of the creek:

Section on the Grant Place.

		Feet.
6.	Soil	2
5.	Shale, sandy, yellow and gray (sampled)	6
4.	Shale, soft, fat, black to drab	5
3.	Sandstone, coarse, yellow	1
2.	Shale, black	2
1.	Coal (exposed)	2

A sample of the top shale that was collected gave the following characteristics: Color olive green to yellow, with occasional brown iron stains. Texture fine, laminated, very fine-grained, soft and uniform. Taste fat. Slacked slowly and perfectly into fine granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 21.5 per cent of water it made a very plastic paste that shrunk 8.0 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 12.0 per cent. Briquettes of the air-dried mud showed an average tensile strength of 189 and a maximum of 207 pounds to the square inch. Incipient vitrification occurred at 1,900° F, complete at 2,100° and viscous above 2,300°. It dried rapidly, but required slow heating and cooling to avoid checking. It burned to a pink to gray, tough, compact mass when vitrified. This bank has not been utilized as yet, but it is well adapted for stoneware.

An analysis gave the following results:

	Per cent.
Silica	57.33
Alumina	25 09
Water	8.74
Sesquioxide of iron	4 09
Lime	0.84
Magnesia	1.17
Alkalies	2 74
Total	100.00
Total detrimental impurities	8.84
Specific gravity	2.26

At Gilkerson ford a sample that was collected by Ladd of the seam of fireclay that outcrops on the bank of the Grand

river, five miles south of Clinton and the details of which are given elsewhere, had the following characteristics: Color light gray and occasionally stained yellow to brown with iron. Texture massive, compact, fine-grained, sandy, and uniform. Taste very lean and gritty. Slacked very slowly and imperfectly. Pyrite was not visible, but white scales of mica were sparingly distributed. When ground to 20-mesh and mixed with 18.0 per cent of water it made a decidedly short to very slightly plastic mass that shrunk 5.3 per cent in drying and 6.0 per cent when vitrified, giving a total shrinkage of 11.3 per cent. Briquettes of the air-dried mud gave an average tensile strength of 54, and a maximum of 60 pounds to the square inch. Incipient vitrification occurred at 2,100° F., complete at 2,300°, and viscous above 2,500°. It dried rapidly, and heated without cracking. It burned to a buff to gray, strong dense body when vitrified.

An analysis gave:

	Per cent.
Silica	76.99
Alumina	14.72
Water	3.86
Sesquioxide of iron	2.48
Lime	0 35
Magnesia	0 58
Alkalies	2.38
Total	101.66
Total fluxing impurities	6.09
Specific gravity	2.36

This clay is almost refractory enough to meet the demands of firebrick. It is well adapted for stoneware, though it is not yet utilized for that purpose.

One mile west of the town of Brownington is the Blair clay pit, from which about 32 cars of 620 tons a month are shipped to the Kansas City Sewer Pipe Co., for sewer-pipe. The top shale and the two seams or potters' clay are worked, which are sold for $4.00 a car of 20 tons, of which $1.00 or five cents a ton is royalty. The following section is exposed at this place:

Section at the Blair Clay Pit.

		Feet.
7.	Soil	1
6.	Sandstone, gravel, yellow clay	1½
5.	Sandstone	½
4.	Shale, sandy	5
3.	Clay, potters'	5
2.	Coal	5
1.	Clay, potters'	4

A sample of the lower potters' seam taken gave the following characteristics: Color light gray, reddish brown, or bluish black, with copious yellow brown iron stains. Texture coarsely lamellar, very fine-grained, soft, uniform. Taste gritty in some layers, though mostly fat and a little of alum. Slacked slowly into coarse granules. Pyrite not noticeable; white mica present in small amounts. When ground to 20-mesh and mixed with 19.0 per cent of water it made a plastic paste that shrunk 6.0 per cent in drying and 6.0 per cent when vitrified, making a total shrinkage of 12.0 per cent. Briquettes of the air-dried mud showed an average tensile strength of 110, and a maximum of 127 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,400°. It required to be rather slowly dried and slowly heated to avoid cracking. It burned to a brown to gray tough dense body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	67.49
Alumina	21.11
Water	5.95
Sesquioxide of iron	2.45
Lime	0.17
Magnesia	0.63
Alkalies	2.83
Total	100.63
Total fluxing impurities	6.08
Specific gravity	2.23

Ladd gives the following section at Montrose, on Price creek (Tp. 40 N., R. XXVIII W., Sec. 26, Nw. qr):

Section at Montrose.

		Feet.
6.	Soil and clay	6
5.	Shale, dark	6
4.	Coal (impure)	½
3.	Clay, potters', outcrop under creek	2½
2.	Shale, sandy, greenish	8
1.	Coal (exposed)	1

The following section in the level country near Deer creek (Tp. 44 N., R. XXV W., Sec. 7, Nw. qr.) is given by Ladd:

Section on Deer creek.

		Feet.
11.	Soil	1
10.	Sandstone	2
9.	Shale, sandy, light colored	4
8.	Shale, black	4
7.	Shale, dark, iron-stained	5½
6.	Coal	1
5.	Fireclay	4½
4.	Coal	4
3.	Fireclay, hard, sandy, considerably iron-stained	6
2.	Shale, black	2
1.	Coal	1½

The two thick seams of so-called fireclay are probably very satisfactory for stoneware.

SHALES.

The area covered by the Clinton sheet is generously supplied with clay-shales suitable for use in the clay industries. Henry county stands second of the counties in Missouri in the magnitude and variety of its clay industries. It is not only making vitrified brick from its shale but is shipping shale to Kansas City, 95 miles distant. The excellent shipping facilities and the cheap coal that results from most of this county being underlain by workable coal seams are great advantages that promise to become of still greater importance in the future in developing the shales and potters' clays. The map of the Clinton district shows the points of outcrop of some of the principal shale beds that are exposed in the banks of the streams. It also shows the favorable railroad facilities.

abundance of water, and the location of manufacturing centers.

The following section occurs on the bank of Town creek one-eighth of a mile below the iron bridge at Clinton, at the bluff known as the "Lover's Leap."

Section at Lover's Leap near Clinton.

		Feet.
5.	Soil	2
4.	Sandstone	15
3.	Shale, gray, blue, thin-bedded, soft and iron-stained	35
2.	Shale, black	1½
1.	Shale, sandy, yellow	3

The shales dip slightly to the north. A sample was collected of the thick bed (No. 3) which gave the following results: Color bluish, lamellar, and mostly very fine-grained, with some coarse sandy streaks. Taste slightly of alum, lean and occasionally very gritty. Slacked not at all. Pyrite occurred in thin streaks one-eighth of an inch thick, with occasional scales of mica. When ground to 20-mesh and mixed with 17.0 per cent of water it made a very lean paste that shrunk 2.0 per cent in drying and 2.5 per cent when vitrified, giving a total shrinkage of 6.5 per cent. It had an average tensile strength of 35 pounds to the square inch. Incipient vitrification took place at 1,800° F., complete at 2,000° and viscous above 2,200°. It dried rapidly and heated without cracking and burned to a dark red body that was lacking in strength, from the leanness of the shale. It is too lean, or lacking in plasticity, to be worked by itself, but makes a fair quality of paving-brick, sewer-pipe, or other coarse ware if mixed with sufficient plastic or bond clay.

An analysis of the shale gave:

	Per cent.
Silica	54.69
Alumina	25.96
Combined water	8 90
Iron sesquioxide	4.97
Lime	8.18
Magnesia	0.15
Alkalies	8.58
Total	96 43
Total fluxing impurities	8.88
Specific gravity	2.26

At the Gilkerson ford on Grand river four miles south of Clinton (Tp. 41 N., R. XXVI W., Sec. 26) is the following section:

Section at Gilkerson Ford.

		Feet.
8.	Sandstone, buff, shaly	5
7.	Shale, blue	2
6.	Coal	1-6
5.	Shale and fireclay	14½
4.	Coal	½
3.	Sandstone	3
2.	Shale, with abundant iron concretions	4
1.	Coal, in river	1½

A sample of the shales was obtained from the above section which gave the following results: Color bluish black, with occasional brown streaks of iron. Texture lamellar, uniform and very fine-grained. Slacked not at all. Pyrite was not noticeable; but mica was abundant as very fine scales. When ground to 20-mesh and mixed with 19.0 per cent of water it made a very lean paste that shrunk 4.5 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 8.5 per cent.

The air-dried mud had an average tensile strength of 76, and a maximum of 81 pounds to the square inch. Incipient vitrification occurred at at 1,800° F., complete at 2,000°, and viscous above 2,200°. It dried rapidly and heated without cracking, and burned to a tough, compact, dark red body.

A chemical analysis gave the following results:

	Per cent.
Silica	55.02
Alumina	21 38
Combined water	8.88
Iron sesquioxide	5.79
Lime	0.58
Magnesia	1.50
Alkalies	3.52
Total	99 47

This clay should be mixed with a "bond" or plastic clay to give the best results, as it is too lean to work satisfactorily by itself. At the Jordan coal mine about three fourths of a mile east of Gilkerson ford, there are:

Section of Strata at Jordan Coal Mine.

		Feet.
3.	Shale, hard, blue, calcareous	15
2	Coal	8
1.	Shale, blue, with iron concretions	9

At the Kinney coal slope, two miles southeast of Clinton, there are ten feet of dark, fine-grained, soft shales over the coal seam. The Pitcher coal shaft, three miles south of Clinton, which is 32 feet deep, gives the following section:

Section at Pitcher Coal Shaft.

		Feet
6.	Soil	1
5.	Shale, hard, bluish, sandy	25
4	Sandstone	½
3.	Shale	1
2.	Coal	2
1.	Shale	6

At the Grant farm (Tp. 42 N., R. XXVI W., Sec. 23) about four miles north of Clinton, the section is:

Section of Shale at Grant Farm.

		Feet.
13	Gravel	8
12.	Clay, potters', plastic	5
11	Limerock, hydraulic	2
10.	Shale, gray, calcareous	2
9	Shale, black, jointed	2
8.	Limerock, hydraulic, irregular, lenticular layers, pyritiferous	1½
7.	Coal	3
6.	Clay, potters,' more or less stained, with non-continuous seam of coal	4
5.	Coal	1
4.	Fireclay	1
3.	Shale, soft, black, fissile	4½
2.	Coal	¼
1.	Shale, very sandy, with sigillaria (exposed)	1

Shale No. 3 was sampled and gave the following results: Color black to gray. Texture laminated, soft, very fine-grained and uniform. Taste strongly of alum and somewhat fat. Slacked readily and completely to granules one thirtieth to one-tenth of an inch in size. No pyrite was visible. When ground to 20-mesh and mixed with 22.0 per cent of water it

made a stiff, plastic paste that shrunk 7.3 per cent on drying and 5.7 per cent when vitrified, giving a total shrinkage of 13.0 per cent. The dry mud had an average strength of 144, and a maximum of 159 pounds to the square inch. It burned from salmon to dark red on the surface, while the interior remained pinkish, it being difficult to obtain a uniform color. The ware rapidly dried, but required to be heated rather slowly to prevent cracking.

An analysis gave:

	Per cent.
Silica	52.70
Alumina	26 86
Combined water	8.86
Iron sesquioxide	4 49
Lime	0.57
Magnesia	0.68
Sulphuric acid	5.19
Alkalies	2 47
Total	101.62

On Field creek, near Clinton (Tp. 42 N., R. XXVI W., Sec. 29, Ne. qr.), the following section occurs:

Section on Field Creek.

		Feet.
14.	Soil	2
13.	Limestone, hydraulic, fossiliferous	1½
12.	Clay, potters', very ferruginous	2½
11.	Shale, black, jointed, with small concretions	1
10.	Shale, black, fossiliferous	6
9.	Coal	2½
8.	Clay, potters', impure	3
7.	Coal and impure fireclay	1
6.	Clay, potters', arenaceous, with sigillaria	1
5.	Shale, black, fissile	5
4.	Coal	½
3.	Clay, potters', impure, sandy	3
2.	Sandstone	½
1.	Clay, varying from paint-clay at top to a fireclay at bottom	2

A sample of the shale No. 5 collected gave: Color blackish gray. Texture laminated, uniform, and very fine-grained. Taste strongly of alum, and rather lean. Slacked slowly and imperfectly to coarse flakes and granules one-tenth to one-fourth of an inch in size. Pyrite was present as minute grains one-fiftieth to one-hundredth of an inch in size, while mica oc-

curred in small amounts as fine scales. When ground to 20-mesh and mixed with 20.0 per cent of water it made a plastic paste that shrunk 6.4 per cent in drying and 4.3 per cent when vitrified, giving a total shrinkage of 10.7 per cent. The air-dried mud had an average tensile strength of 115, and a maximum of 139 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,850°, and viscous above 2,050°. It burned to a dense, tough body that had a handsome red color. It dried rapidly, but required to be slowly heated to avoid cracking. It is suitable for terra cotta, paving-brick and sewer-pipe.

The analysis gave the following results:

	Per cent.
Silica	54.44
Alumina	22.98
Combined water	11.96
Iron sesquioxide	5.86
Lime	0.38
Magnesia	0 69
Alkalies	3 02
Total	100.82

At the Vickers farm about seven miles southeast of Clinton, and just outside of the Clinton area (Tp. 41 N., R. XXV W., Sec. 30, Ne. qr.), in an old bluff of Grand river, is the following section:

Section at the Vickers Place.

		Feet.
5.	Slope	20
4.	Sandstone, much contorted, apparently ferruginous	17
3.	Ironstone, hard	½
2.	Shale, micaceous, sandy	14
1.	Sanstone (exposed)	1

A sample of the shale gave: Color light pink to brown, with copious iron stains. Texture laminated, very fine-grained, with some sandy streaks. Taste mostly smooth and fat, but some portions gritty. Slacked slowly into thin plates and coarse granules. No pyrite was visible; sparing scales of white mica were present; showed fine roots, indicating that it was a surface sample. When ground to 20-mesh and mixed with 23.0 per cent of water it made a stiff, plastic paste that

shrunk 7.6 per cent on drying and 6.7 per cent when vitrified, giving a total shrinkage of 14.3 per cent. The air-dried mud had an average tensile strength of 140, and a maximum of 157 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,900°, and viscous above 2,100°. It burned to a compact, strong body with a bright red terra cotta color. It dried rapidly, but needed some care in burning, to avoid cracking. It is well adapted for paving-brick, terra cotta and sewer-pipe.

An analysis gave the following results:

	Per cent.
Silica	59.06
Alumina	23.05
Combined water	6.03
Iron sesquioxide	7.31
Lime	0.46
Magnesia	0 86
Alkalies	2 80
Total	99.57
Total fluxing impurities	11.43
Specific gravity	1.93

At the Blair Diamond coal shaft, one mile southeast of Deepwater there are over 17 feet of hard blue shale over the coal seam. At the Keith and Perry shaft No. 1, one-half mile northeast of the town occur 20 feet of hard, sandy shale over the coal seam, and an underlying bed of shale. The shaft is 60 feet deep. About one mile east of Deepwater, coal is worked by stripping the 15 feet of drab shale resting on the seam. One mile southeast of the town the Missouri Clay Co. works a bank of shale about 100 yards east of the factory. The section is:

Section at Missouri Clay Pit.

		Feet.
10.	Soil	1
9.	Loess	6
8.	Clay, jointed, brown to gray	6
7.	Clay, gray	2
6.	Shale, yellow, sandy, coarsely laminated	5
5.	Coal	1½
4.	Clay, potters', olive to buff, shaly	8
3.	Sandstone, soft, gray, argillaceous	2
2.	Shale, soft, gray, fat	6
1.	Shale, black	5

The shale No. 2 was sampled and gave the following results: Color bluish to light gray, with abundant yellow to brown iron stains. Texture finely laminated, and sandy in streaks. Taste somewhat lean, and occasionally gritty. Slacked slowly but almost completely into granules one-eighth to one-fourth of an inch in size. Pyrite was not noticeable; mica scales were present in small amounts. When ground to 20-mesh and mixed with 21.0 per cent of water it made a plastic paste that shrunk 5.7 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 9.7 per cent. The dried mud had an average tensile strength of 124, and a maximum of 140 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 2,000°, and viscous above 2,200°. It dried rapidly and heated without cracking, and burned to a compact, strong, dark red body. It is well adapted for paving-brick, sewer-pipe and terra cotta.

A chemical analysis gave the following results:

	Per cent.
Silica	68.54
Alumina	18.49
Combined water	4.62
Iron sesquioxide	3 38
Lime	1.03
Magnesia	0 88
Alkalies	2.87
Total	99.25
Total fluxing impurities	7.76
Specific gravity	2.82

At the Dickey sewerpipe works at Deepwater is the following section:

Section at Dickey Pit.

	Feet.
4. Soil	½
3. Loess, or yellow clay	3
2. Clay, very ferruginous, gray	3
1. Shale, soft brown	10

The section is not persistent nor uniform, and the above is an average. A sample taken gave the following results: Color bluish black to light gray, with considerable yellow to brown iron stains. Texture laminated and course to fine-

grained, mostly the latter. Taste, fat and gritty. Slacked very slowly and imperfectly into coarse granules. No pyrite was visible. When ground to 20-mesh and mixed with 21.0 per cent of water it made a plastic paste that shrunk 5.8 per cent in drying and 3.3 per cent when vitrified, giving a total shrinkage of 9.1 per cent. The dried mud had an average tensile strength of 100, and a maximum of 110 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,850°, and viscous above 2,000°. It dried rapidly and heated without danger of cracking, and burned to a strong, compact, dark-red body.

An analysis gave :

	Per cent
Silica	60 12
Alumina	21 35
Combined water	6 32
Iron sesquioxide	7.06
Lime	0.82
Magnesia	1 09
Alkalies	3.43
Total	99.88
Total fluxing impurities	12.09
Specific gravity	2.07

It is well adapted for paving-brick, sewerpipe and dark terra cotta. It is used for sewer-pipe.

RESIDUARY CLAYS.

The surface clays are used for the manufacture of ordinary building brick at Clinton, and occasionally at other places. There is no important industry based upon their occurrence and use. A better grade of clay is so abundant that the residuary clays are not so extensively used as in those parts of the state less favored.

GUMBO.

Within the last few years this clay has become the basis of a large industry in the state. The clays are the dark alluvial clays of the floodplains of the larger streams of the state. They are used for the manufacture of railway ballast. They could be used for making road material. They are burned in long heaps and without moulding or other preparation except-

ing the burning. The organic matter disappears and the product assumes a reddish or brick color. The industry has never been developed in Henry county, though there is an inexhaustible supply of the clay in the broad valleys of Grand river and Big and Deepwater creeks.

CLAY INDUSTRY.

The clay manufacturing industries of the area may be grouped under three heads: Pottery or stoneware, and sewerpipe, and draintile and brick.

Pottery.—The seat of pottery manufacture within the area is at Clinton. There are three potteries engaged in the work and the combined product amounts to about $68,000.00 annually. The number of men employed varies with the demand for the product, averaging about 150. One of the potteries is operated by steam, the engine being 60-horsepower capacity. This is the largest pottery in the state. The other two are operated by horse power. The clay is obtained at Calhoun, Brownington and at Clinton. The product is sold in western Missouri, Kansas and the Indian Territory. A great deal of the product is hauled in wagons to the inland towns of central Missouri.

Sewerpipe.—The sewerpipe industry of the area is located at Deepwater. The clay is obtained at the same locality and the product finds a market in Kansas City and neighboring towns and in Kansas. The manufacture was begun here in 1886. The town depends upon this industry for its support. The value of the product in 1891 was $150,000.

Paving-Brick.—The Missouri Clay Company of Deepwater engages in the manufacture of paving-brick in the Clinton area. The plant was begun in 1890. In the following year the value of the product was $19,500. The clay is mined at the works. Paving-brick are also manufactured at the Sewerpipe works.

Common Brick.—Building brick are made at Clinton and Deepwater. Three yards at Clinton produce nearly half a million brick annually. Common brick are manufactured at Deepwater also, but the output is small.

ROAD MATERIALS.

The material in the Clinton area available for road-making consists of stone and clay. The stone for this purpose is the coal measure limestone of the northern part of the sheet. There is not a large supply of it that is readily available. Its use would necessitate a crushing plant since it does not occur in gravel beds. The chert fragments from the lower Carboniferous rocks of the eastern part of the county are better for this purpose and will probably be utilized before many years.

The strong alluvial clays or gumbo of the floodplains of the larger streams are now being used in many parts of the state for railway ballast after it is thoroughly burned. When thoroughly burned it is very serviceable for highways. The area of the Clinton sheet has an inexhaustible supply of material in the great floodplains of Grand river and Big creek.

BUILDING STONES.

The Clinton district is not very well supplied with good building stone. It is only a few miles away, however, to an abundant supply. Some of the limestones of the area make a very good stone for foundations, but they are not utilized to any great extent. The limestone associated with the Tebo coal is used locally and serves the purpose very well. It is easily quarried, is not too heavy to be easily broken and handled with ordinary tools, and is quite durable, except in exposed situations it is liable to break into conchoidal blocks from hard freezing. Some of the sandstones of the southern and southeastern parts of the area could be utilized locally for the same purpose. They will probably never be the basis of a great quarrying industry, but they will supply a limited local demand. The limestones of the extreme northern part of the sheet could also be utilized.

LIME.

There is no lime made. None of the limestones are sufficiently pure to yield a good white lime. The proximity of the beds of lower Carboniferous limestones which are among the best lime-producers in the world render it certain that the thin limestones of the coal measures cannot be utilized.

CEMENT.

The bed of impure limestone overlying the Tebo coal is often referred to as the hydraulic limestone. It has never been tried. Its appearance indicates that there is a possibility that it may be utilized for this purpose in the future. It closely resembles the Fort Scott cement rock.

SANDS.

The sandstones of the southern part of the sheet are the only sources of this material within the area. Where a stream drains a sandstone area altogether, considerable quantities of loose sand can usually be gathered in its bed. Where it cannot be obtained in this way the only way of getting it is to crush the rock. There are no deposits of glacial sand in the region.

WATER SUPPLY.

The water supply may be classified under three heads: streams, springs and wells.

Streams.—The creek and river waters of the Clinton area are abundant when compared to that of other areas of the same kind in the region. Their value arises from their use as stock water. They are not used for domestic purposes at all and their use as a motive power is very slight. The streams flowing the year round are all down to grade. The fall is only a very few feet to the mile. The streams all flow through regions of soft rocks and as a result the water is discolored by the suspended matter which it always carries. The water con-

tains no matter, however, which renders it unpleasant to the taste. It serves as an excellent and wholesome water for stock and the supply in the larger streams is unfailing. Grand river, Big, Deepwater, Bear, Marshall, Field, Honey and Town creeks carry water throughout the year.

Springs are not an important factor in the water supply of the region. The nature and structure of the rocks do not favor their formation. The closeness in texture of the predominant rocks—shales—does not permit the rainfall to be absorbed to any considerable depth nor to be collected into underground streams. There is not a large flowing spring in the area. There are a few places where water collects in depressions by seepage but these are rare.

Wells furnish the domestic water supply of the region. In the northern part of the area water is usually found where any of the three beds of limestone of the Henrietta formation are encountered. There are also a few sandstone beds which are water-bearers. In the southeastern part of the area, the sandstone beds of the Cherokee shales afford a supply of good water.

The most important well water of the area is that derived from the six deep wells at Clinton. The oldest of these wells, the Clinton Artesian, was drilled in the summer of 1887. At a depth of 425 feet the flow of water was 200 gallons a minute. This was called "sulphur water." The drilling was continued down to a depth of 800 feet at which level the flow was about 400 gallons a minute. That part, 200 gallons a minute, which came from the last 400 feet was excellent. The improvements around the well consist of an artificial lake, bath houses, pavilions and a hotel. (See plate V.) The water is used for both drinking and bathing purposes. An analysis made by Woodward gave the following results:

	Grains in gallon
Silica	0.6834
Lime	9 5883
Magnesia	4 9239
Potassa	1.1682
Soda	33.0016
Sulphur trioxide	5.3679
Chlorine	42.0202
Carbon dioxide	15.7822
Water in combination	3.2281
	115.7138
Oxygen	9.4682
Mineral matter	106.2456
Fixed residue	95.1264

United as follows:

	Grains in gallon.
Silica (SiO_2)	0 6834
Calcium bicarbonate ($CaH_2(CO_3)_2$)	16 7231
Magnesium bicarbonate ($MgH_2(CO_3)_3$)	11.1125
Calcium sulphate, ($CaSO_4$)	9.1254
Magnesian chloride ($MgCl_2$)	4.4639
Potassium chloride (KCl)	1 8518
Sodium chloride (NaCl)	62.2853
Mineral matter	106.2454

The water may be classified under muriatic waters.

The Water Works well is only a short distance away from the Clinton Artesian. It is 800 feet deep, but its water differs considerably from that of the Artesian. An analysis made by Woodward of the water from the well shows:

	Grains in gallon.
Silica	0.2336
Lime	6 5711
Magnesia	3.5838
Potassa	2.9847
Soda	16.0629
Suphur trioxide	4 4567
Chloride	19.6316
Carbon dioxide	14.4388
Water in combination	2.9896
	70.9026
Oxygen	4 4374
Mineral matter	66.4752
Fixed residue	56.4752

United as follows:

	Grains in gallon.
Silica (SiO_2)	0.2336
Calcium bicarbonate ($CaH_2(CO_3)_2$)	9 9844
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	12 9984
Sodium bicarbonate ($NaHCO_3$)	2.4050
Calcium sulphate ($CaSO_4$)	7.5764
Potassium chloride (KCl)	4.7292
Sodium chloride (NaCl)	28.6482
Mineral matter	66.4752

The Clinton Artesian well No. 3 is about one mile north of the other two. It is 913 feet deep. It has a flow of nearly 300 gallons a minute. The water has a strong odor of hydrogen sulphide. The well was drilled in 1891. An analysis of the water from this well by Schweitzer shows:

	Grains in gallon.
Silica	0.8177
Lime	8 6447
Magnesia	1 3142
Potassa	1.3142
Soda	27.7681
Chloride	32.7972
Sulphur trioxide	4 4099
Carbon dioxoide	18.1784
Water in combination	3.7183
	101.9416
Oxygen	7.3909
Mineral matter	94.5507
Fixed residue	81.7432

United as follows:

	Grains in gallon.
Silica (SiO_2)	0 8177
Calcium bicarbonate ($CaH_2(CO_3)_2$)	16 0778
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	15.6688
Calcium sulphate ($CaSO_4$)	7.4978
Sodium chloride (NaCl)	52.4010
Potassium chloride (KCl)	2 0852
Mineral matter	94.5483

All three of these wells are located on the floodplain of Town creek in the western part of the city. The elevations of the tops of all three is about 690 feet above tide water. About 40 feet of coal measures were penetrated first, then about 150 of lower Carboniferous limestones. The rest of the depth is through the limestones and sandstones of the Silurian.

Since the above data on the three wells mentioned were first gathered there has been drilled three additional deep wells at Clinton. Dr. Britts furnishes the following statements regarding them: "The first is at the pumping station of the Clinton waterworks. The well is 500 feet deep, 8 inches in diameter and flows about 200 gallons a minute. The water is the same as in well No. 2, being located only 70 yards to the west, and flows into one of the basins of the stations. The other two wells are at the Clinton ice plant about 1000 feet northeast of the court house on one of the highest points in the city limits. These are not flowing wells. They are ten feet apart, the first 8 inches in diameter, drilled in 1894, and the second 10 inches in diameter put down in 1896. Both are 650 feet deep. The water rises to within 100 feet of the top and each is supplied with a deep-well pump, with cylinder 250 feet down. The two have a capacity of 240 gallons a minute, which has small effect upon the supply in the wells, which probably exceeds 1000 gallons a minute. No analysis of these waters has been made but the water is similar to that of the others, an alkaline water with hydrogen sulphide to appreciable extent. The strata passed through as far as could be learned was as follows:

Section of Wells at Clinton Ice Plant.

		Thickness.
10.	Soil and clay	12
9.	Sandstone and sandy shale	21
8.	Coal	1/3
7.	Shale	19
6	Sandstone, very hard, disintegrating on exposure to the air	8
5.	Shale and sandstone	87
4.	Chert (lower Carboniferous)	45
3.	Shale, red	20
2.	Limestone (lower Carboniferous and Silurian)	400
1.	Sandstone, saccharoidal, with rounded grains of pure silica	40

"The difference in the elevation of the top of these wells and those in Town creek valley is about 75 feet."

The Ford well at Montrose appears to be supplied by a spring. It is 25 feet down and the water is obtained by pumping. The results of a chemical analysis by Woodward are as follows:

	Grains in gallon.
Silica	0.5140
Ferric oxide	2.8490
Lime	35.7008
Magnesia	6.7964
Potassa	1.1000
Soda	8.5197
Sulphur trioxide	64.6280
Chloride	0.0752
Carbon dioxide	15.5754
Water in combination	3.1858
	138.4443
Oxygen	0.0169
Mineral matter	138.4274
Fixed residue	127.4539

United as follows:

	Grains in gallon.
Silica (SiO_2)	0.5140
Ferrous bicarbonate ($FeH_2(CO_3)_2$)	5.2265
Calcium bicarbonate ($CaH_2(CO_3)_2$)	28.9161
Calcium sulphate ($CaSO_4$)	66.6243
Magnesium sulphate ($MgSO_4$)	20.3892
Potassium sulphate (K_2SO_4)	1.8516
Sodium sulphate (Na_2SO_4)	19.5128
Potassium chloride (KCl)	0.1590
Mineral matter	138.1925
Oxygen for FeO	0.2349

SOILS.

The soils of the area are of two kinds: Sedentary and transported. The area lies south of the drift region and by far the greater part of it is covered by sedentary soils. The character of the soil depends upon the character of the rocks which underlie it, or at least these give it its distinguishing and most prominent constituents. Owing to the inevitable creep of soils they become pretty well mixed, even in an area of so-called sedentary soils. It may be further borne in mind that the soil now on the surface is the undissolved residue from the decomposition, not only of a thickness of rock represented by the thickness of the soil but of a greater or less thickness

of originally overlying rocks. In most cases these very probably have been considerable and doubtless of greatly varying character and composition. Even without a mixing of the soils by creep, there will generally be a greater variety of constituents than could have been derived from the underlying rocks. Yet, notwithstanding this the rocks just below the superficial deposits over the area of the Clinton sheet exert considerable influence on the soils. The greater part of the rocks of the area are shales and sandstones, the former breaking down to a stiff clay. This kind of soil in an area with so low relief, furnishing such poor surface drainage, makes a soil rather difficult to cultivate, but where well drained it is a good producer.

In the northern and northeastern parts of the area, where the limestone beds crop out, the soil partakes of their character and is thereby enriched. Over all the southeastern portion, excepting in the vicinity of Deepwater, the area is overlain by sandstone. The soil is thin but easily tilled and well drained.

The transported soils have been derived from rocks of the same general character as these now found within the area. They are essentially, therefore, of the same chemical composition, but the constituents are more thoroughly mixed. They are confined to the alluvial plains of the streams and altogether cover a considerable portion of the area. They are black and generally argillaceous, and when they have been drained and tilled have proved to be very productive. At the present time only a very small portion has ever been brought under tillage on account of lack of drainage and the periodic overflows from the streams. Near the channels of the streams there is a strip which is sufficiently well drained to produce a vigorous growth of timber. This part is the product of a more recent floodplain-building of the stream and is composed of gravel, sand and clay, while the greater part of the floodplain is made up of clay. The latter part bears no timber excepting a few scattering laurel oaks.

With an extensive system of under-drainage and dike-building these bottom lands may become very important factors in the wealth of the area. Without it they will probably remain for a long time at least, nothing better than grazing lands.

ACKNOWLEDGMENTS.

For kindly aid, constant interest during the progress of the work and for much valuable information special acknowledgments are due to Dr. J. H. Britts, of Clinton, and to him grateful thanks are tendered. He has in many ways freely given suggestions and facts, which his long residence in Clinton has enabled him to accumulate, and to which much of this report owes its value. The list of coal plants is based entirely upon the specimens in his collection, many of which were originally described from this locality from the forms collected by him.

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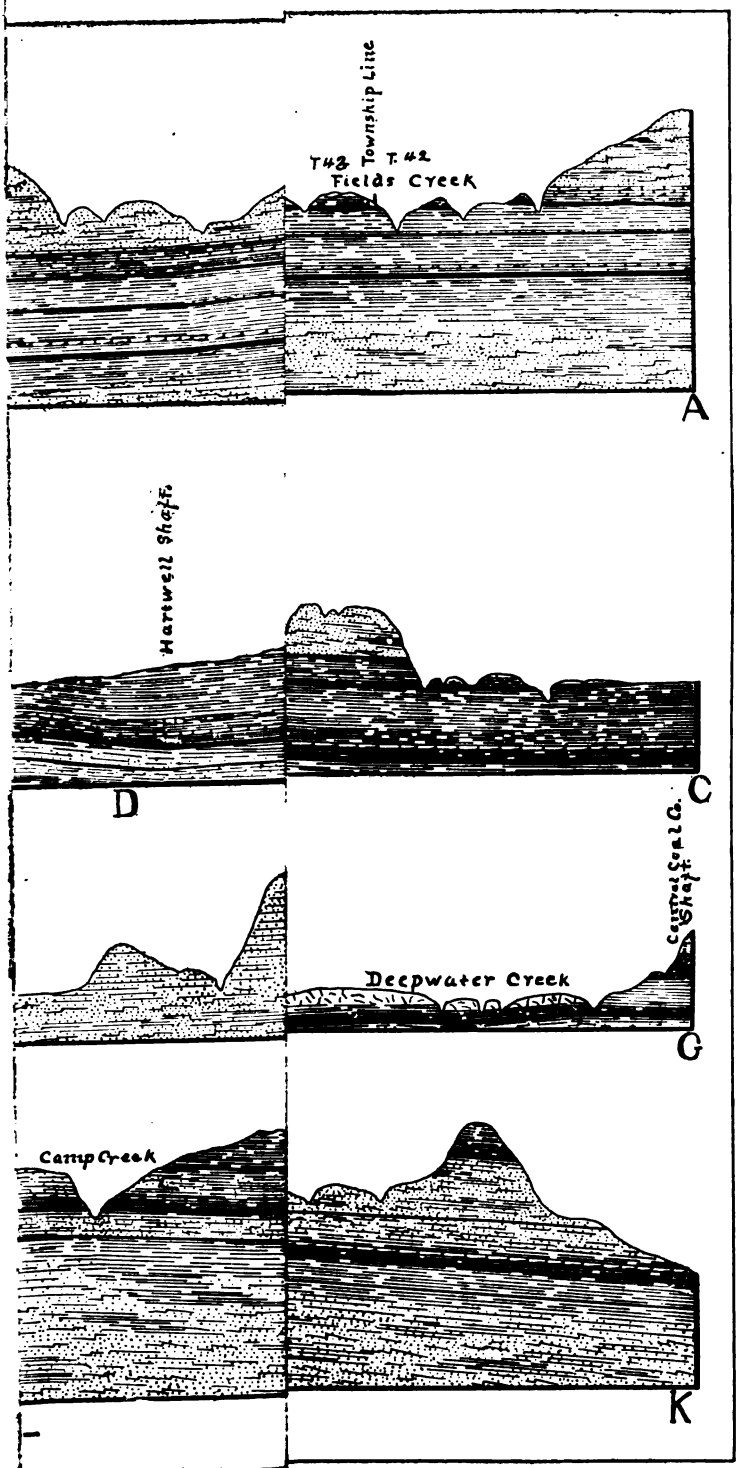
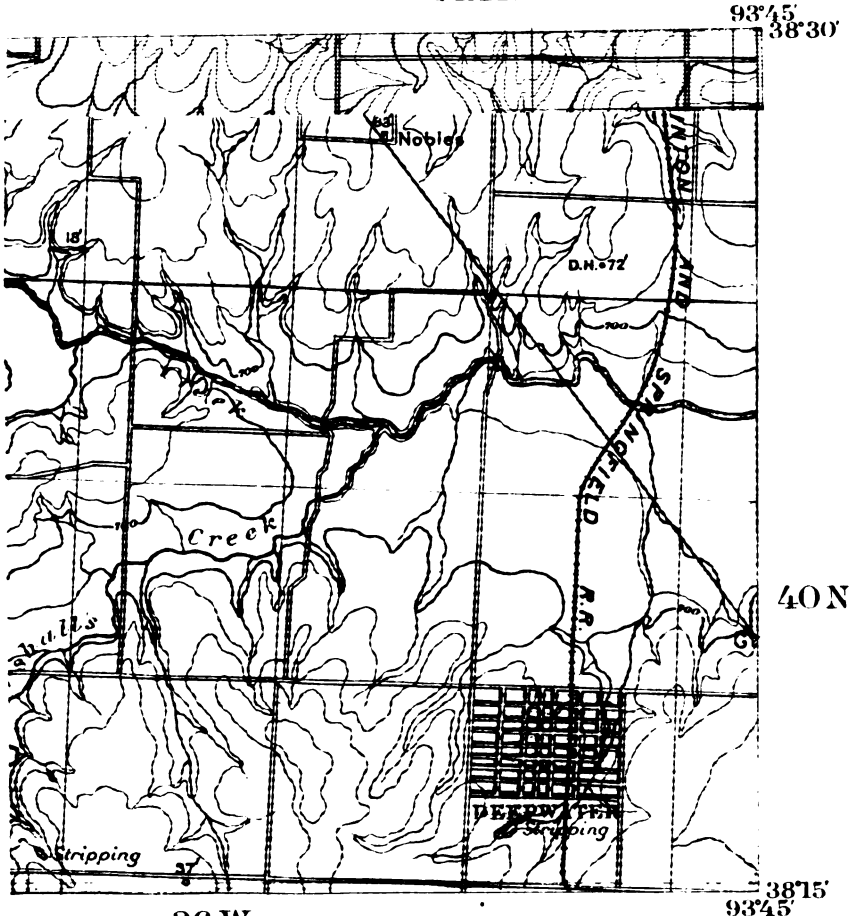


s, Clinton Quadrangle.

CLINTON SHEET



CONVENTIONAL MARKS

▮ Shaft	~~ Geological Boundary	S.H. School House
• D.H. Churn Drill Hole	▫ Building	Sh Shale
L.S. Limestone	Ch Church	S.S. Sandstone

GEOLOGICAL DESCRIPTION

OF THE

CALHOUN SHEET.

GEOLOGY OF THE CALHOUN SHEET.

BY CURTIS FLETCHER MARBUT.

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INTRODUCTION.

LOCATION AND AREA.

The district occupied by the Calhoun sheet is in Henry and Benton counties, and is named from its principal town. The area is quadrilateral, of 15′ extent in latitude and longitude. It is bounded by the meridians 90° 30′ and 90° 45′ of longitude west of Greenwich, and the parallels, 38° 15′ and 38° 30′ of latitude. It comprises an area of about 230 square miles all of which, excepting about 15 square miles which lie in Benton county, are contained in the eastern half of Henry county. The northern limit of the area is about 4 miles south of the northern line of the county; and the southern limit is about the same distance north of the southern boundary. The western limit lies about 2 miles east of the mid-line of the county. Its position in the state is west-central. (Figure 7.)

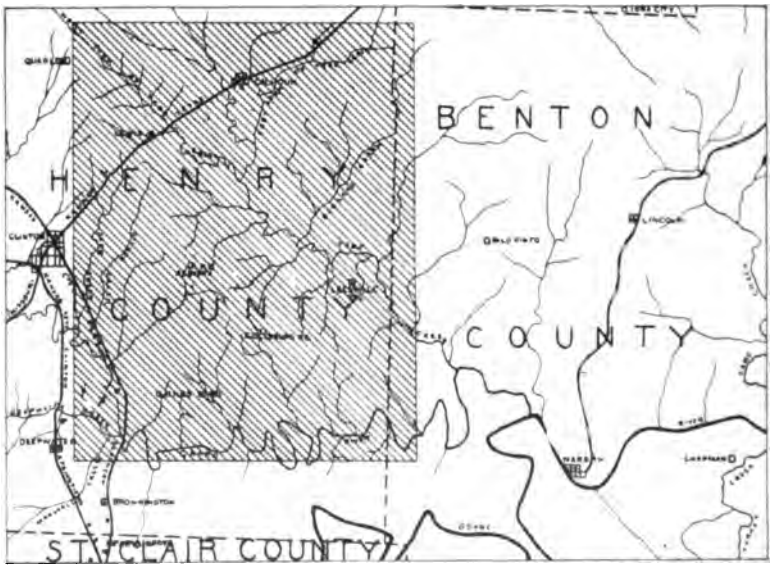


Figure 7. Outline Map showing Position of Calhoun Sheet.

PREVIOUS WORK WITHIN THE AREA.

The area occupied by the Calhoun sheet was first examined geologically in 1872, when Broadhead and Norwood made a

reconnoissance of Henry county, the former *passing from Winsor southwestward along the Missouri, Kansas and Texas railroad; and the latter †from Fort Lyon southwestward, down Barker creek to Leesville; and from there northwestward, up Tebo creek, to the vicinity of Calhoun.

Norwood encountered no rocks higher than the lower sandy beds of the lower coal measures (Des Moines series), except at the Munn coal mine where the near shore equivalent of the limestone beds of the middle part of that formation was found. Most of the exposures examined were of the lower Carboniferous limestone which were displayed on Tebo creek in the neighborhood of Leesville. A visit was made to the old Osage shaft located two and one-half miles southwest of Calhoun. A record of the shaft was obtained and the workings of the mine described.

The outcrops observed by Broadhead showed also the lower sandstone and shales of the lower coal measures. A section was examined in the neighborhood of Calhoun, one on the Park place one and one-half miles north of Calhoun, one at the Neff coal mine two and one-half miles to the east, and one at Dillons, three miles northeast of the same place.

PHYSIOGRAPHY.

SURFACE RELIEF.

Main Features. The area lies on the southern slope of the Missouri-Osage divide. Its highest parts nowhere reach the height of the upland forming that divide, which is ten miles beyond the northern boundary of the sheet. As a whole the topography of the area is past maturity.

Probably no part of the upland is a remnant of the original constructional surface. It is the product of the present cycle; and where it is of low relief, or gently undulating with wide open valleys, is nearly down to grade. Such areas are underlain by exceedingly soft rocks.

*Geol. Sur. Missouri, Report on Iron Ores and Coal Fields, pt. II, pp. 21-26, 1872.

†Ibid., pp. 12-16.

The features of the region express in a very marked degree the geological structure and relative resistance of the rocks. The latter are nearly horizontal yet dip gently northwestward

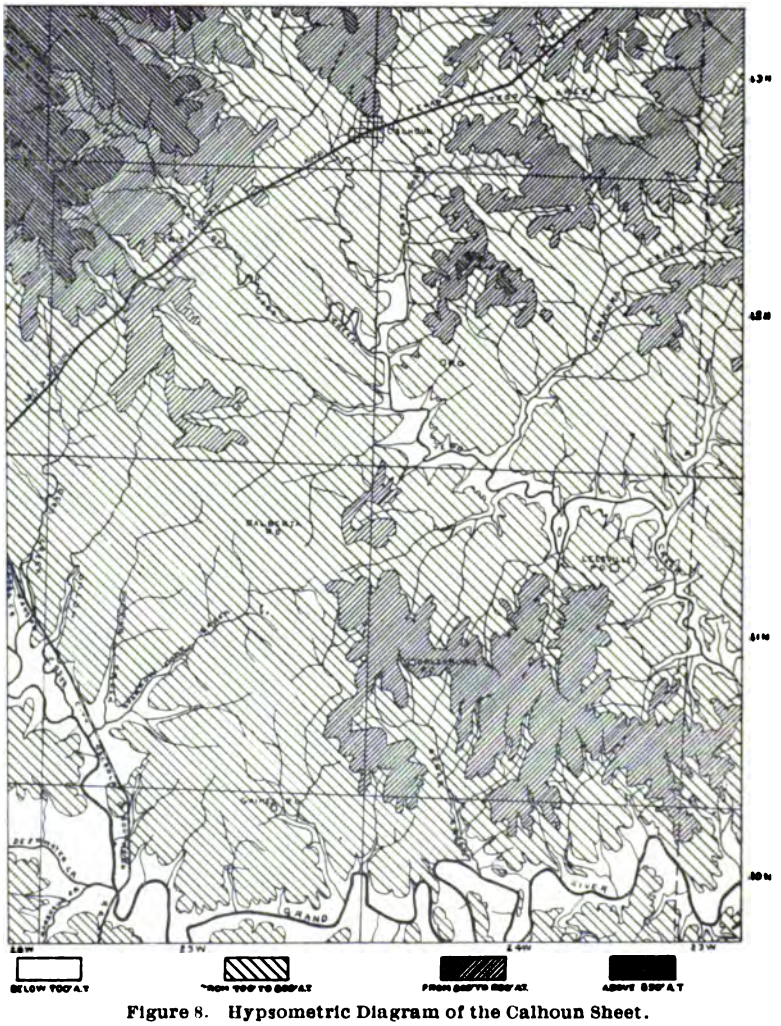
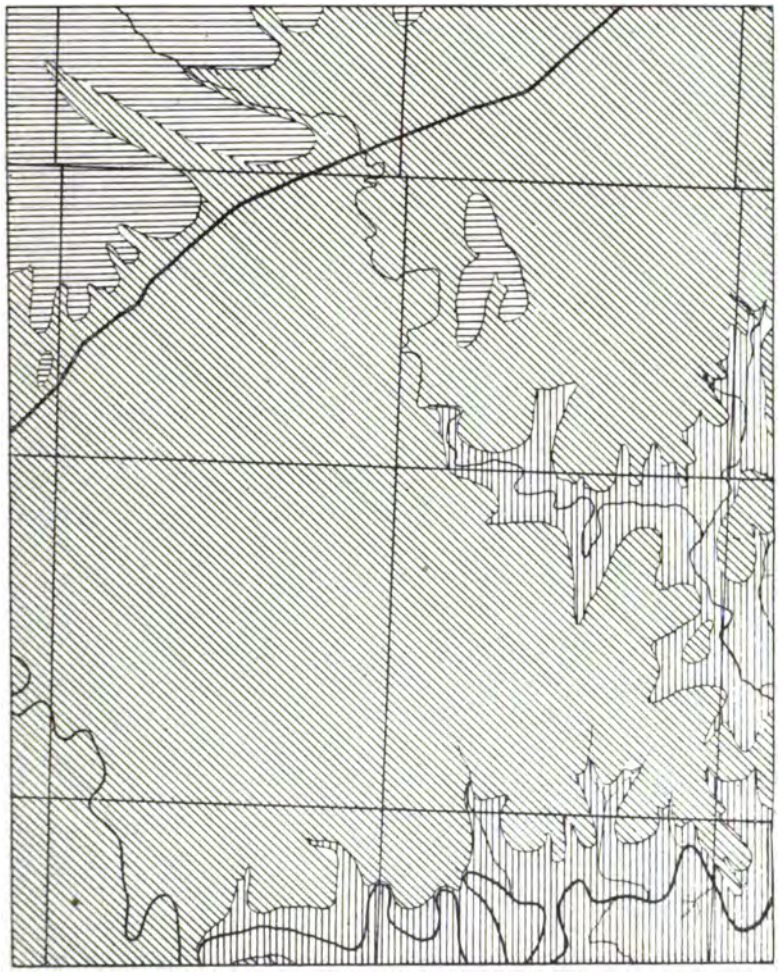


Figure 8. Hypsometric Diagram of the Calhoun Sheet.

without pronounced folding or faulting. Higher and higher rocks outcrop in succession in the direction of the bedding slope. The strike of the strata is about due northeast and

southwest. The drainage is almost directly against the dip. The lowest rocks are exposed in the southeast, and the highest in the northwest corner of the area.



Warrensburg Upland. Nevada Lowland. Springfield Upland.

Figure 9. Physiographic Belts of the Calhoun Area.

When compared with one another on the basis of relative resistance to degradation the rocks of the area naturally fall

into three groups, a lower set of resistant beds, a median set of soft layers and an upper set of resistant strata. These three sets of rocks have given rise to as many well marked zones of surface relief, the belts formed by the outcrops of each set being different stages of advance in the cycle. The physiographic belts are, however, not confined alone to the area under consideration but are wide-spread features characterizing the topography of a large part of southwestern Missouri and are coextensive with the surface exposure of the rocks on which they are developed. Owing to their wide extent and their physiographic importance they have recently received special names, the titles being taken from the places in the vicinity of which the features are best developed. They are: the Warrensburg upland, the Nevada lowland and the Springfield structural plain. The areal distribution of these zones is shown on the accompanying sketch map (figure 9).

Warrensburg Upland. That part of the first mentioned district within the borders of the Calhoun sheet lies northwest of the line of the Missouri, Kansas and Texas railroad. It constitutes the area of high and somewhat rugged land around the headwaters of Tebo creek known as the high point of Tebo, and is merely the southern serrated edge of the upland of Johnson and Pettis counties, which is continuous with the Warrensburg upland in Lafayette and Johnson * counties where it is typically developed. It forms the divide between the streams flowing northward into the Missouri river and those flowing southward into the Osage.

The foundation and persistent strength of the upland immediately north of the Calhoun area are the limestone beds of the Henrietta formation. Within the area of the sheet it is reduced from its constructional elevation and is cut rather sharply by the streams flowing southeastward into Grand river. Only the lower beds of limestone remain. The tops of the ridges form a nearly even surface rising gradually northward toward the summit of the upland and lie about eighty feet above the general level of the Nevada lowland below. The

*Missouri Geol. Sur., Vol. x, pp. 68-71, 1896.

highest part of the upland back from the stream is a gently undulating plain. From this, ridges run southward and southeastward like the fingers of an open hand, becoming gradually lower until they end more or less abruptly in a faint escarpment near the line of the railroad. Their former continuation is shown in places by outlying remnants which are now reduced to small mounds capped by limestone. A rather large outlier exists on the east side of Tebo creek southeast of Calhoun.

Nevada Lowland. As a central plain this division includes the greater part of the area. It extends in a broad belt bounded on the northwest by the southeastern border of the Warrensburg upland and on the southeast by the sharply dissected area of the Springfield structural plain. Its irregularities of elevation are not great. Its features are determined by the series of very soft sandstones and shales of the lower coal measures. Where shales prevail the relief is faint, the valleys are shallow, wide-open troughs, and the profiles are rounded. Where sandstones predominate the valleys are sharp, the hills angular in profile, and higher; the general relief stronger. The sandstones have an irregular areal distribution. As a rule, however, they occur near the base of the coal measures. The shales lie above the sandstones but below the limestones which constitute the uplands of the norhwestern part of the sheet. The northern and western sides of the lowland are gently undulating; while the southern and southeastern parts are somewhat rugged, passing gradually into the Springfield structural plain. The larger streams cut shallow valleys, though they are nearly everywhere bordered by steep bluffs formed by the basal sandstones of the coal measures, the permanent grade over the greater part of the belt being in or below the sandstones.

The Nevada lowland extends southwardly and southwestwardly far beyond the limits of the sheet. It is interrupted by the strip of hill-land bordering Grand river. It appears again on the narrow divide south of the river, between it and

the Osage, although interrupted by the valley of the latter stream, and extends southwestward beyond the state limits.

It is a lowland of denudation, the result of the present cycle of erosion. It is excavated along the strike of the soft shale and sandstone beds of the inferior portion of the coal measures.

Springfield Structural Plain. The southeastern hill-land, which borders Grand river and Tebo creek, is a narrow zone extending across the southern and southeastern parts of the district, with an embayment on the eastern side along Tebo creek. It is the result of the erosion of Grand river and its tributary streams upon the resistant limestones of the lower Carboniferous formation. It is a part of the western edge of an extensive, gently northwestwardly sloping plain formed on the upper surface of the lower Carboniferous limestones. It is a typical structural plain determined by the position of a bed of relatively hard rock to whose surface it conforms and on which general degradation halts for a while after the originally overlying softer beds (shales and sandstones of the coal measures in this case) have been removed. The general form of the surface depends upon the attitude of the rocks determining it.

That part of the plain lying within the Calhoun sheet is deeply dissected by Grand river and its tributaries. It occupies a zone on each side of the stream extending nearly across the area and a small strip on Tebo creek extending to a point about one mile above Leesville. The permanent grade of the river lies below the top of the limestones. A narrow channel has been cut into them, down almost to permanent grade and its tributary streams have excavated narrow ravines into the adjacent uplands. The intervening ridges do not waste away so rapidly as the streams erode their channels. The result is a belt of rugged hill-land along the streams, separated by broad level areas bordered by steep slopes.

The present arrangement of the main drainage is against the dip of the rocks and must therefore be of latter date than the original uprising at the close of Carboniferous time. It

was initiated on an even surface of beveled beds and its present direction is due to an eastward tilting of this old surface, which occured probably about the close of Cretaceous time.

River Meanders. A characteristic feature of Grand river is its strongly and symmetrically meandering course. This is shown in the accompanying sketch (figure 10) and the topographic map.

The reason of this highly characteristic action of this stream, and others of similar habit in southern Missouri, has been the subject of considerable discussion recently. On the one hand the meanders are explained on the supposition that they are inherited from a former meandering of the same stream on a floodplain when the country stood lower than at present. As the country was elevated the river continued in its meandering course while cutting its channel down to a lower grade, at the same time expanding the meanders. On the other hand an attempt is made to show that it is not necessary to suppose a former base-leveling of the country such as is implied in the wide floodplain of the former period, but that the meandering course is the result of the action of the stream in cutting its channel downward from an original slightly irregular course.

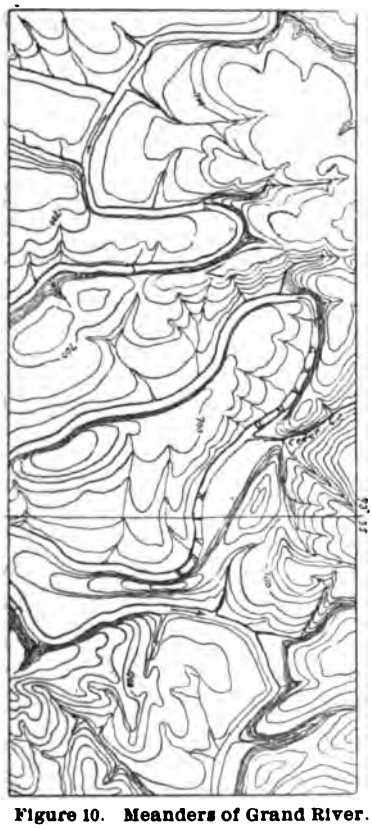


Figure 10. Meanders of Grand River.

The topography of this part of the Mississippi basin has the unmistakable stamp of youth in the steep-sided valleys of the Mississippi and Missouri rivers and the narrow gorges of many of their tributaries. Where mature features are assumed

they are due to the very slight resistance of the rocks on which they are developed. By comparing these features with similar ones found elsewhere the age of which has been clearly demonstrated it seems conclusive that the present cycle cannot date backward farther than the end of Cretaceous time. Prior to this period, at least just before the beginning of the present cycle, the country must have stood near sea level, since there is no sign whatever of a former cycle which was interrupted before its work was completed. This condition could prevail as the result either of subaerial base-leveling or of an original elevation which barely raised the area above the sea.

Another feature of the drainage of the area and of the country immediately westward is the position of the stream-channels in their floodplains. All the watercourses which flow either eastward or southeastward through a floodplain closely hug the southern bluff. It is very noticeable in the branches of Tebo creek which occur in the Calhoun district and of Grand river and Big creek to the west. It is a feature too general to be considered merely accidental. An explanation demonstrably correct has not been found; it may be due to a slight warping causing a gentle southward tilt of the surface after the streams had attained their present size.

DRAINAGE.

The largest watercourse within the Calhoun area is Grand river. It is itself but a small stream. It is not navigable and is easily fordable at ordinary stages of the water. During a protracted drought the water becomes very low. Within the area under consideration its valley is narrow and its sides are steep. It is, however, about down to grade. In the softer rocks west of the district it has long since reached its grade and has developed a wide floodplain. It drains a large area to the west including nearly all of Cass and Henry counties and the northern part of Bates county. It flows into the Osage a few miles east of where it leaves the Calhoun sheet. It continues its meandering course to its mouth.

Tebo creek is the next largest stream. It drains nearly the whole of the northern and northeastern parts of the district. It branches into numerous tributaries which spread widely. Excepting in the region of the more resistant limestones and cherts of the lower Carboniferous it has reached its grade and all of its larger branches have opened floodplains of considerable width. Even in the harder rocks it is cutting its channel very little, though it has not yet had time to open a wide valley. It flows into Grand river a short distance beyond the eastern limit of the area.

Pretty Bob, Cedar and Sparrow Foot creeks are tributaries of Grand river from the north. They are all small branches, the two former running for part of their length through the rugged hills of the lower Carboniferous rocks. The latter flows through the soft shales of the coal measures. Its valley is wide and open.

STRATIGRAPHY.

GENERAL GEOLOGY OF THE REGION.

The indurated rocks of southwestern Missouri are chiefly of upper Paleozoic age. Besides the Silurian, which extends into the district from the east, they consist of (1) the Mississippian (lower Carboniferous) limestones, and the Des Moines shales (lower or productive coal measures.) All lie nearly horizontal, yet dip gently to the northwest. Each formation therefore outcrops in a belt of greater or less width running in a northeast and southwest direction.

The Mississippian series forms the limestone floor upon which the productive coal measures are laid down. In west-central Missouri, of which the Calhoun area forms a part, only the lower half of the series appears to be represented. The Kinderhook beds and the Augusta limestone are well developed. Owing to erosion previous to the deposition of the coal measures the upper part of the lower Carboniferous, which includes the St. Louis and Kaskaskia formations in the eastern portion of the state does not occur. However, characteristic fossils of the former have been found in the loose

residuary chert fragments overlying the other limestones, showing clearly that a part at least of the superior members were at one time present.

The inferior portion of the lower Carboniferous preserves all characteristics which are so well displayed both to the northeast and to the southwest of the district. The Kinderhook in this part of the state is represented chiefly by the upper calcareous division, the Chouteau limestone. The median shales are entirely absent. The Augusta limestone consists of two well marked divisions, the thinly bedded cherty strata and the massive encrinital beds, which correspond chiefly to the lower and upper Burlington sections at the typical locality in Iowa and in the northeastern part of Missouri.

The coal measures (Des Moines series) consist of three subdivisions conformable with one another, yet easily separable lithologically. They represent the prevalency of three sets of conditions of sedimentation. There is no very sharp line of separation between the members but the lithological and probably also the faunal features of each produced at the culmination of its particular controling conditions are distinct from those of the others. The most important difference between these beds, however, is the effect that they have had on the physical features of the area which they underlie. In fact, the clear recognition of their existence as so many geologic individuals came partly from a study of the physiography of this portion of the state. Their existence over a great portion of the territory has been determined and their continuity over the whole area in this way proved. Their outcrops form three easily recognized physiographic belts continuous over most of the region. The relation of the rocks to the topography has been made out in only one part of the region, but the connection is so close and the relation of cause and effect so evident here that there is no hesitancy in predicting the main features of the geology from the relief features determined from the topographic maps and from observations made while rapidly traversing the country.

The basal member of the coal measures consists of sandstones and shales. The former lie at the bottom, are variable in thickness, and grade upward into the shales. The sandstone beds are not persistent in thickness over all the territory but merge laterally as well as vertically into shales. Physiographically the belt occupied by these deposits is a lowland of denudation produced during the present cycle of topographic development. The series is best displayed both vertically and in geographic distribution in the extreme southwestern part of its extent in the state. These rocks are the Missouri representatives of a similar sucession of rocks in Kansas which have been called the Cherokee shales by Haworth. The same term is adopted in this report. Where the formation is best developed in Bates, Vernon and Barton counties it is about 275 feet thick; northward it becomes thinner.

The beds are the same in character as those which skirt the eastern edge of the coal measures elsewhere in the state. They are not so thick north of the Missouri river as they are south of it, and are not sharply separated from the overlying beds either by lithological character or physiographic effect. The characteristic development of the formation and the place where the importance of recognizing it as a distinct geologic unit is best shown, is in the wedge-shaped area extending from Windsor, in Henry county, as the apex of the triangle, southwestward, the boundaries on the one side being the line of the Missouri, Kansas and Texas railroad and the Osage river to the state line, and on the other side by the southeastern margin of the coal measures. The area opens into southeastern Kansas.

The second member of the coal measures is made up of a succession of limestones and shales and varies from 80 to 125 feet in thickness. Owing to its great development near Henrietta, in Johnson county, it is proposed to call it the Henrietta formation. Limestone is a prominent component and in places forms a very considerable part of the vertical section. The change from the Cherokee shales to the limestones is gradual. Thin limestone beds appear in the upper part of the former but

they are generally impure and are always of limited geographic extent. The formation is shown in a belt of upland running along the strike, dropping off abruptly on its southeastern side as a more or less clearly defined escarpment to the lowland excavated on the soft beds of the Cherokee formation, and on the northwestern side merging into the upland plain whose features are determined by the next overlying beds.

The Henrietta formation enters the state just north of the Marais des Cygne river, in Bates county, and from there its outcrop runs northeastwardly through Henry, Johnson and Lafayette counties. It may be traced for a long distance north of the Missouri river. From the state line, through Bates and Henry counties, the escarpment formed by its outcrop is an important physiographic feature, but in Lafayette county and northward the resistant limestones lie too near the grade of the larger streams to have any important topographic effect. They rise to the eastward to be sure, but at the same time they become thinner and extend further from the larger streams, so that they do not become of importance in the relief of the country. The thickness of the formation in Henry and Johnson counties is about 100 feet.

The third set of strata belonging to the coal measures comprises 100 to 150 feet of beds which are almost exclusively argillaceous and sandy shales. There are some thin sandstone beds among them, a thin bed or two of coal, and near the bottom and top of the member several thin layers of limestone. The top of the formation is the summit of the productive coal measures (Des Moines series), which has recently been placed at the base of the Bethany limestone. The formation is the extension in Missouri of the Pleasanton shales of Kansas.

It is one of the best defined and most widely developed members of the coal measures; it is found both north and south of the Missouri river. Its superficial extent is bounded on the west and northwest by the escarpment of the overlying Bethany limestone and on the east by the escarpment formed by the Henrietta limestone just described.

Physiographically the belt occupied by this formation is a lowland almost down to the grade of the streams draining it. It is one of the most extensive and pronounced physiographic zones within the limits of the state.

GENERAL RELATIONS OF FORMATIONS.

In the area covered by the Calhoun sheet are rocks of the Silurian and Carboniferous ages. The former barely appear within the boundaries of the district so that their geographic extent is very small. They are exposed only in and near the bed of Grand river in the extreme southeastern corner of the district.

The Carboniferous beds cover almost the entire area, and include representatives of two out of the total four series, which constitute the system. The Carboniferous rests unconformably upon the Silurian, but both sets of strata are so nearly horizontal that the physical break in sedimentation is not noticeable in a marked degree. The discordance between the beds of the lower and upper Carboniferous is much more pronounced. The recent deposits of the area include the alluvium of the river and creek valleys.

The formations represented in the Calhoun district are shown in the following table:

Table of Formations of the Calhoun Area.

SYSTEM.	SERIES.	FORMATIONS.
Recent.		Alluvium.
Carboniferous.	Des Moines (Coal measures.)	Henrietta limestones.
		Cherokee shales
	Mississippian (Lower Carboniferous.)	Augusta limestones.
		Kinderhook limestones.
Silurian.	Calciferous.	Magnesian limestones.

General Section. It is impossible to construct a general section of the rocks of the area that will give for all localities the details of the stratigraphy. Along the same stratigraphic horizon several kinds of rock may appear. They were deposited at the same time but under varying conditions. This is particularly true of the lower beds of the coal measures. Above the irregular deposits of the lower sandstones there is greater persistence of the individual beds. The conditions of deposition were more uniform, the old inequalities of surface were filled up, and the sea floor was practically even. As the region progressively sank the area became one of open-sea conditions and the deposits were correspondingly affected. The Tebo coal bed with its associated overlying limerock may be considered as the first deposits of the general section which were laid down when uniform conditions prevailed over a considerable area. These must not, however, be considered of indefinite extent, but they continue over a large part of the area and may be traced far beyond its limits into adjoining districts. With these facts in mind the accompanying general section is compiled (figure 11).

The section includes only those beds which crop out within the area of the Calhoun sheet. There have been no deep wells drilled into the lower beds. The latter beds are exposed at the surface east of the district, however. The upper 30 to 40 feet are limestones underlying which is a sandstone less than 100 feet thick, beneath which there are limestones again. The sandstone at the top of the section is assumed to be the southern extension of the Warrensburg sandstone. It lies in an eroded channel in the coal measures, and is presumably of Carboniferous age. The actual connection with the Warrensburg bed has not been traced.

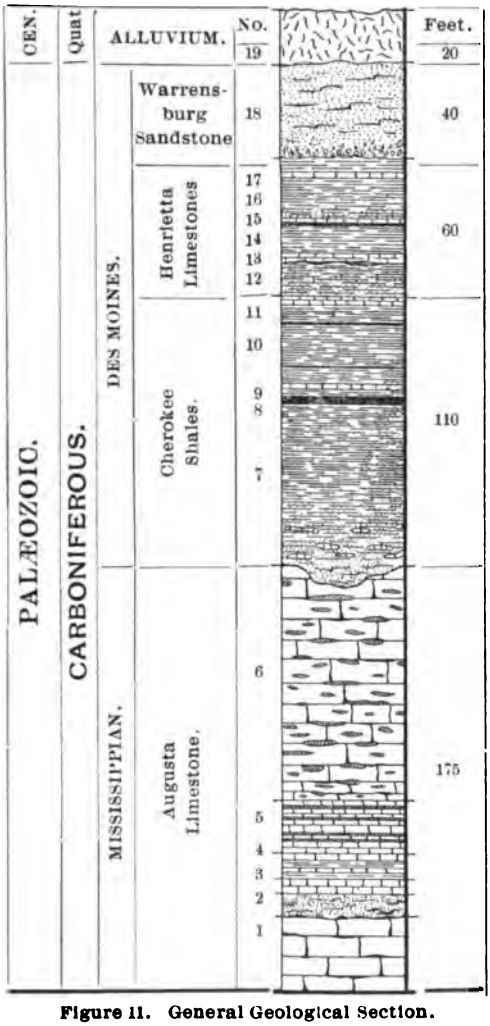


Figure 11. General Geological Section.

The rocks from the Tebo coal upward, are well exposed along Tebo creek northwest from Lewis station to the head of the creek. The Warrensburg sandstone occurs on this stream in the extreme southeastern part of the district. The rocks between the Tebo coal bed and the lower Carboniferous rocks are well shown along Tebo creek southeast of Lewis station and south and east of Calhoun.

The lower Carboniferous rocks crop out on Grand river, the particular occurence given in the general section being exposed in a ravine on the north side of that stream (Tp. 40 N., R. XXIII W., Sec. 7, Ne. qr.)

In a gradually sinking basin of deposition it would be naturally expected that the higher beds would overlap and extend farther shore-ward than lower ones and that a higher bed would retain its off-shore characteristics farther westward or southwestward, in case the land from which the sediment was derived lay in that direction. This is just what is found to be the case here. The Tebo coal bed and its overlying limestone cannot be traced much farther south or east than the line of the Missouri, Kansas and Texas railroad, but what is interpreted to be the same as the Spangler coal bed with its overlying limestone is found in the high lands two miles southeast of Calhoun where the underlying rocks to the base of the coal measures are, so far as known, exclusively sandstones and shales. (See section 1 on plate VII.)

TYPICAL EXPOSURES.

STANDARD SECTIONS.

A few of the most characteristic sections serve as standards for comparisons of the details of stratigraphy.

The succession of the lower Carboniferous beds as they are exposed in the southeastern corner of the area on Grand river, are best shown six miles directly south of Leesville (Tp. 40 N., R. XXIII W., Sec. 7.)

I. Section on Grand River, South of Leesville.

		FEET.
7.	Sandstone, (coal measures)	20
6.	Slope, chert-covered, (Mississippian)	80
5.	Limestone, gray, coarse, encrinital; contains chert distributed in nodular masses, and in discontinuous layers between the beds	80
4.	Limestone, rather fine-grained, drab, somewhat earthy; contains small crinoid stems, and much chert, the latter abundantly distributing in thin layers alternating with thin beds of limestone, and also in nodular masses throughout the limestone	80

		FEET.
3.	Limestone, similar to above, but somewhat shaly; contains small crinoid stems, but no chert, and graduates into both the overlying and underlying beds	10
2.	Limestone, fine-grained, compact, bluish-gray, containing pyrite, but no chert; beds are 2 to 6 inches thick, and often separated by an inch or two of greenish shale	6
1.	Limestone, (Silurian,) magnesian, heavily bedded, (exposed)	7

The details of the coal measures of the southwestern part of the area have been disclosed chiefly in coal shafts. One phase of these strata is shown at the Central mine located one-half mile east of Deepwater (Tp. 40 N., R. XXVI W., Sec. 12.)

II. Section at Central Shaft, near Deepwater.

		FEET.
6.	Soil and clay	15
5.	Sandstone, soft and shaly	6
4.	Shale, blue to black	9
3.	Shale, calcareo-silicious, graduating on the one hand into argillaceous sandstone and on the other into clay shale	20
2.	Shale, bituminous	1
1.	Coal	3

The Jordan shafts and drill-holes were sunk several years ago about one mile northeast of North station, and three miles north of the Central shaft (Tp. 41 N, R. XXVI W., Sec. 25.) The record of the deepest one is as follows:

III. Section at Jordan Shaft, near North Station.

		FEET.
8.	Soil and clay	8
7.	Sandstone, shaly, white and gray	6
6.	Shale, gray, calcareo-arenaceous	28
5.	Coal	3
4.	Clay, light colored	3
3.	Shale, or soft sandstone, brownish ochreous	22
2.	Shale, blue	13
1.	Shale, red, white, with lower Carboniferous chert fragments	24

Another phase of the rocks of the lower part of the coal measures is shown in the mine on the Lake property about three miles southeast of Clinton (Tp. 41 N., R. XXV W., Sec. 18, Se. qr.)

IV. Section at Lake Shaft, southeast of Clinton.

		FEET.
15.	Soil	6
14.	Sandstone	½
13.	Clay	4
12.	Sandstone	¼
11.	Shale, argillaceous	80
10.	Clay	4
9.	Limerock, bituminous	2
8.	Coal	1·6
7.	Shale, black	2
6.	Coal	¼
5.	Shale, argillaceous	10
4.	Limerock, pyritiferous	2
3.	Coal	3
2.	Clay	¼
1.	Sandstone, hard	8

The coal-bearing rocks of the eastern and northeastern parts of the area are well exposed on Tebo creek, about two and one-half miles southeast of Calhoun.

V. Outcrop on Tebo Creek, Southeast of Calhoun.

		FEET.
6.	Concealed, with scattered pieces of chert, containing *Productus muricatus, Spirifer planoconvexus, and Chonetes mesoloba*	17
5.	Limestone, hard, blue and drab, silicious	2
4.	Shale, drab at top, becoming black lower down	20
3.	Coal	3
2.	Sandstone and shale	20
1.	Sandstone	70

The base of this section is about 20 feet above the base of the coal measures. The rocks making up this interval of 20 feet are well exposed farther down the creek and are all sandstones. The lower 60 feet of the strata of the section is the equivalent of the section at the Lake shaft. The beds of of the upper part are the equivalent of those found to the west, in the Bowen shaft, the record of which as determined by Dr. J. H. Britts (Tp. 42 N., R. XXV W., Sec. 17, Se. qr.) is:

VI. Section at Bowen Shaft, Southwest of Lewis Station.

		FEET.
24.	Limestone	2
23.	Shale, light drab	1¼
22.	Limestone, concretionary	½
21.	Shale, black, massive	2½
20.	Shale, light colored	8

		FEET.
19.	Shale, white, argillaceous	8
18.	Shale, black, bituminous	2
17.	Coal	½
16.	Clay	9
15.	Shale, jointed, bituminous	2
14.	Shale, sandy	12
13.	Limestone, hard, blue	2½
12.	Shale, calcareous, with fossils	8
11.	Shale, bituminous, massive	2
10.	Coal, with concretions	2½
9.	Shale, light colored	9
8.	Shale, black	½
7.	Coal, with pyritiferous concretions	8
6.	Shale, sandy, light colored	12
5.	Shale, dark colored, bituminous	7
4.	Coal	½
3.	Shale, bituminuous	7
2.	Coal (mammoth bed)	5¼
1.	Shale, pyritiferous	18

Number 22 of this section is considered the equivalent of No. 5 of section V, and No. 17 the equivalent of No. 3 of the same section. The sandstones below No. 3 in section V are the equivalent of the rocks of section VI lying below No. 17.

Three miles west of Calhoun (Tp. 43 N., R. XXV W., Sec. 28) a well gave the following record:

VII. Record of Well, west of Calhoun.

		FEET.
13.	Soil and clay	7
12.	Clay, red, sandy	5
11.	Flint? in bowlders	1
10.	Clay, sandy	4
9.	Limestone	1
8.	Shale, red	4
7.	Clay, and concretionary limestone	1
6.	Shale, hard	8
5.	Limestone, hard, blue	2
4.	Shale, black	2½
3.	Coal	1
2.	Shale, hard, gritty	7
1.	Limestone	1

About 800 feet northeast of the well is an outcrop on Tebo creek. The top of the section is not more than 15 feet below the horizon of the bottom of the well. The rock reported in the bottom of the well is possibly the upper part of the sandstone at the top of the creek section (Tp. 43 N., R. XXV W., Sec. 28, Se. qr.)

VIII. Exposure on Tebo Creek.

		FEET.
5	Sandstone, on the slope (exposed)	3
4.	Limestone, carrying chert in nodules	5
3.	Shale	25
2.	Coal	1
1.	Shale, (exposed)	20

Number 4 of this section is the same as No. 24 of section VI, and No. 5 of section V.

SECTIONS IN THE SOUTHERN TIER OF TOWNSHIPS.

There are included in this series portions of the northern parts of four townships, included in township 40 north, ranges XXIII to XXVI west With the exception of scattered blocks of sandstone or possibly a few feet of sandrock in place, on the top of the hill in the western part of section 6, no coal measures occur in that part of Tp. 40 N., R. XXIII W. which lies within the area of the Calhoun sheet. The lower Carboniferous rocks are exposed to a thickness of 160 feet. South of Grand river, between that stream and the Osage, no coal measures appear. The upland between these two streams is so narrow that the soft shales and sandstones have been stripped off. There are isolated spots of sandy soil in places where the surface of the upland is flat over a considerable area, showing that the coal measures were there until recently. About two miles west of the eastern side of Tp. 40 N., R. XXVI W. the sandstones appear and are continuous westward along the upland. They are correlated with those north of Grand river, both on lithologic and stratigraphic grounds, and the latter are classed as coal measures for the reason that they are unconformable upon the lower Carboniferous rocks, and carry coal beds to within a few feet of their base. They are not separated from the undoubted coal measures above them by any other characters than would result from a simple change of conditions in sedimentation and they are conformable with them.

In that part of this township which lies within the area, the strata of the coal measures do not occur abundantly, ex-

cepting in the northwestern corner. In the northern and northeastern parts sandstones extend southward in thin narrowing tongues on the upland between the secondary drainage lines of Grand river. In section 4, Ne. qr., coal is reported to have been mined several years ago. The seam occurs a few feet above lower Carboniferous limestones. In the northeast quarter of section 8 sandstones of the coal measures extend to the top of the cliff overlooking Grand river; and again in the southwest quarter of the same section. The base of the sandrock lies about 100 feet above the water in the river. The texture is rather coarse, but is rarely pebbly. Conglomerates made up of waterworn chert pebbles are occasionally found.

Westward, the sandstone approaches nearer and nearer to the level of the water in Grand river. In Tp. 40 N., R. XXV W., Sec. 13, the top of the lower Carboniferous limestone is less than 40 feet above the water level. Beyond, there is a slight rise at first of the top of the lower rocks, and in section 15 it is again nearly 100 feet above the river; but in section 21, the coal measures come down to the water level. In the southern part of section 9 the lower Carboniferous limestone rises about 20 feet above the water, but soon disappears. At the bridge crossing Grand river, in section 17, Nw. qr., the top of the lower Carboniferous rocks lies in the bed of the stream. Still farther northward, in sections 5 and 8, they rise a few feet above the water, but soon disappear. In section 2, Se. qr., at the Peeler spring, the following sequence is shown:

IX. Outcrop at the Peeler Spring.

		FEET.
4.	Sandstone, rather coarse-grained, brownish red, (about 750 feet A. T.)	40
3.	Concealed, with sandstone seen in places	15
2.	Sandstone	½
1.	Limestone, gray, sub-crystalline, with abundant crinoid remains (exposed)	1

One mile northeast of this locality is an old coal stripping. The excavation is now nearly filled with debris, but the coal is said to be 14 to 16 inches thick. It is overlain by several feet of light colored, rather sandy shale. Thin sandstone slabs lie scattered over the surface on top of the hills near the place, and half a mile farther north sandstone is abundantly exposed in the ravines. About 500 feet northeast of the center of section 1, of this township, a bed of coal 22 inches in thickness was reported to have been encountered in an excavation not more than six feet deep.

Coarse red sandstones underlie the country near Gaines postoffice and northward, and extend southward also to the top of the bluffs overlooking Grand river. The coarse character of the deposits is not persistent, for there is a passage laterally and vertically into beds of finer material. This feature aids in producing a characteristic topography. The uplands between the drainage areas are not of even crest line, nor does the land slope toward the streams with the regularity and accordance of elevation of ridge tops that is seen in a country of uniformly resistent horizontal rocks; but the softer parts wear out rapidly leaving the more resistent sandstones as isolated mounds. The result is a strongly hummocky relief. At the Duckworth coal mine (Tp. 40 N., R. XXV W., Sec. 9, Ne. qr.) the strata shown are:

X. Section at the Duckworth Mine.

		FEET.
4.	Soil and clay (about 715 feet A. T.)	5
3.	Coal	½
2.	Shale, black, in one place with a thin lens of coal	2
1.	Coal	1½

One-half mile to the east is a stripping which is now abandoned. Between this and the localities in section 1, no coal has been reported. The rocks are well exposed, yet a coal bed associated with shales could easily be hidden from view. It is probable, however, that if coal were present it would have been discovered in the ravines running southward, or in the wells of the neighborhood.

In the western part of section 9, and the eastern part of section 8, the surface slopes gradually down to the river and very little sandstone is seen. On the Gorff property, in the northwest quarter of section 5 of this township, shales are exposed to a considerable thickness in a steep hillside on the east side of Grand river, where they have been preserved by a capping of sandstone. The section is as follows:

XI. Outcrop on the Gorff Place.

		FEET.
4.	Concealed, with large sandstone blocks at top and shales exposed lower down (about 775 A. T.)	50
3.	Shale, argillaceous, drab	15
2.	Coal	2½
1.	Shales, argillaceous	50

South and southeast of Brownington, sandstone is the principal indurated rock exposed, but north and west of the town, the rocks are soft shales which, in breaking down, produce an undulating topography. Northwest of the center of section 19 a shaft thirty feet deep, in soft shales, passed through thirty inches of coal at the bottom. In the bank of Cooper creek, 800 feet west of this place, a few inches of coal are exposed about 20 feet above the water. In the northeast quarter of section18, at the Dunlap coal pit, the following sequence of rocks occurs:

XII. Section at the Dunlap Stripping.

		FEET.
7.	Soil and clay (about 700 A. T.)	5
6.	Shale, gray, soft	6
5.	Shale, bluish-black	8
4.	Shale, dark, bituminous, soft	½
3.	Coal	½
2.	Coal, bony	1-6
1.	Coal	2

There are in this vicinity a number of strippings and shafts which are worked rather extensively. The principal mine is the Diamond shaft, now abandoned, located in the southern part of section 13. A drill-hole about 300 feet to the southwest passed through the following strata:

XIII. Record of Drill-hole near Diamond Shaft No. 1.

		FEET.
7.	Soil, (about 730 A. T.)	2
6.	"Gravel"	6
5.	Clay, light colored	12
4.	Shale	1
3.	Shale, calcareo-arenaceous (hard rock)	45
2.	Shale, dark, argillaceous	2
1.	Coal	3

In shaft No. 1 the same rocks as those in the drill-hole were passed through, but the "hard rock" was only 36 feet thick. The old shaft No. 1 operated by the same company but long since abandoned was located 1200 feet north of the drill-hole. The record is:

XIV. Record of Diamond Shaft No. 1 (old mine).

		FEET.
5.	Soil, (about 725 A. T.)	2
4.	Clay, yellowish	7
3.	Shale, blue	7
2.	Shale, black	2⅓
1.	Coal	3

No "hard rock" is reported. The blue shale bed is its equivalent. Nearer the outcrop it becomes soft and in most places on exposure breaks down into ordinary sandy clay. The section at the Dunlap stripping shows it where it has become so soft that 15 or even 20 feet of it can be readily stripped off in mining the coal.

In the Central shaft (section 12, Sw. qr.) the same hard, shaly, light colored arenaceous rock was met with and had a thickness of 20 feet. The coal seam worked at these places is often undulatory. The bed is slightly thinner on the ridges. The shales overlying the coal bed for several feet contain abundant fossil plants perfectly preserved.

Loose chert lies in the creek bed a few hundred feet east of these localities and only about 20 feet below the coal bed. There is probably no coal below.

SECTIONS IN SOUTH MIDDLE TIER OF TOWNSHIPS.

The south median tier of townships embraces those in 41 north, ranges XXIII, XXIV, XXV, and XXVI west. In that

part of Tp. 41 N., R. XXIII W. which lies within the Calhoun area, sandstones of the coal measures cap the ridges and uplands, and lower Carboniferous rocks are exposed everywhere along the creeks. The sandstones are apparently identical with those described as occcuring to the south and southwest.

In Tp. 41 N., R. XXIV W., Sec. 36, Ne. qr., a bed of coal about three feet thick, with a shale band one foot from the bottom is exposed in a shallow pit. It is overlain by five feet of drab shale. The excavation exposes the face of the coal for a distance of 50 feet. At the western end the coal bed becomes noticeably thinner. Half a mile to the northwest in the southwest corner of section 25, another coal bed 18 inches thick was struck at a depth of 40 feet. Both of these deposits belong probably to the same seam though it is not certain that the intervening space is underlain by it continuously. Sandstones do not occur prominently in the vicinity. The rocks are principally shales yet they grade into sandstones within short distances in all directions. On Tebo creek and on its principal tributaries through the township lower Carboniferous rocks are everywhere exposed. In the eastern part sandstone occurs on the flat uplands, its base being 150 feet above the water in Tebo creek. Westward it gets lower and lower until it lies within less than 50 feet of the water, in the northwestern part of section 4, and disappears entirely within a little more than half a mile farther up the creek. Over the rest of the township sandstones and shales are everywhere exposed. Coal is reported to have been encountered in a well at Colesburg post-office in section 18, at a depth of only a very few feet. No other occurrences are reported in the township.

In Tp. 41 N., R. XXV W. there are a relatively large number of shafts, wells and outcrops. The southeastern corner of the township is characterized by the coarse red sandstones extending northward from the vicinity of Gaines post-office. These with their characteristic topography extend over the southermost two tiers of sections east of 29 and 32. Along Pretty Bob creek, in sections 35 and 36 frequent fragments of chert occur in the stream bed. Near the base of the coal

measures the sandstone is coarse and often pebbly, the latter being noticeable near the school house in the northwestern portion of section 25. Further northward, along the eastern side of the township, shales become more abundant and the topography is more undulating.

In section 13, Nw. qr., a seam of coal one foot thick is reported in a well at a depth of 20 feet. The altitude of the top of the well is 790 feet above tide. A bed is also reported to occur in two places in section 14. In each case the thickness is given as 12 to 15 inches. The seams lie at an elevation of about 790 feet A. T. Coal is also said to occur in the southwest corner of section 15, but at present the bed is concealed. Coal was mined at one time near the center of the east half of this section. For the most part sandstones and shales are the only strata exposed, and these are to be seen in every ravine. The former are very abundant in the southern part of section 16, and the northwestern part of section 21. At the northern side of the former the sandstone beds are thinner and shales are more abundant, In section 27, Nw. qr., a bed of coal which is nearly four feet thick is being mined at the Gerhart stripping. The hillsides above the seam are made up of sandstones and shales the former predominating, though rather thinly bedded. What is presumably the same seam occurs near the southwestern corner of section 28. It lies at about the same elevation as the bed at the Gerhart mine, or about 720 feet A. T. Westward, no other outcrops of coal are found along this branch. Where the wagon road crosses it, 40 rods south of the center of section, fragments of chert occur abundantly in the channel. At the eastward turn of the road just south of the bridge soft sandy shales are exposed, but higher up the hill sandstones appear again. Southward on the uplands the sandstones are found in thin beds. Near the middle of the south line of section 32 the railroad passes through a cut in which 20 feet of arenaceous and argillaceous shales are exposed, with a sandstone capping the hill. About 300 yards to the southwest is the locality described in section XI.

In the extreme northwestern portion of section 29 coal was taken out at one time from a mine in the bed of the creek. Where the road crosses the stream south of the mine a bed of sandstone crops out in the channel.

In section 20, Sw. qr., coal has recently been mined in a shaft 20 feet deep. Work is now abandoned and the dump shows nothing except soft argillaceous or slightly sandy shales. The coal is said to be three feet thick. The topography of all the southern part of section 20 indicates clearly that no very hard beds occur at the surface. Near the middle of the north line of section 30, on the Wicker place, coal has been taken out by drifting. The mine was opened several years ago. In 1892 an attempt was made to operate rather extensively but on account of the variability in the the the thickness of the seam the plan could not be carried out. The coal is overlain by sandstone. The latter rises as a rather sharp ridge, the beds being horizontal however, the western side being steep to the Grand river floodplain, and the eastern side gradual to Sparrow Foot creek. The ridge extends northward but soon merges into a flat upland, the western face remaining steep. Coal has not been found along the bluff except at the locality mentioned. Sandstone is also prominently exposed along the road where it crosses the stream in the northwest quarter of section 19. Beyond the creek no strata are found until after the road leaves the township.

In section 17 some exposures of special interest occur. Coal is reported in a well on the north side of the southeast quarter of the section. In the road east of the well, continuing to the top of the hill thinly bedded sandstones and sandy shales are exposed. About a quarter of a mile northwest of the well on the western side of the same tract is the Neighberger drift. The strata shown are:

XV. Section at the Neighberger Coal Mine.

		FEET.
4.	Clay, and blue shale grading into blue, shelly limestone (about 715 A. T.)	8
3.	Limerock, blue, irregularly bedded, with pyrite layers	4
2.	Shale	¼
1.	Coal	3½

The shale overlying the coal seam becomes much thicker in places and contains calcareous concretions carrying fossils. Most of the latter appear to be *Spirifer lineatus* and *Productus muricatus*. The limerock contains a few large Producti. Just across the land line, about 300 feet from the mine, is the Carpenter drift, now abandoned. The thickness of the coal is about the same as at the Neighberger opening. Immediately over the seam are two feet of gray shale, and then one and one-half feet of limerock. Three-quarters of a mile westward is the Lake shaft. The record given is:

XVI. Record of Lake Shaft.

		FEET.
16.	Soil (about 730 feet A. T.)	6
15.	Sandstone	½
14.	Shale	4
13.	Sandstone	½
12.	Shale, argillaceous	80
11.	Shale	4
10.	Limerock	2
9.	Coal	⅓
8.	Shale, black	2
7.	Coal	½
6.	Shale, argillaceous	10
5.	Limestone, pyritiferous	2
4.	Coal, with a thin band of shale 12 inches from the bottom	3
3.	Clay	⅛
2.	Sandstone, hard	8
1.	Coal (?)	1-6

Numbers 11 and 14 were reported to be potter's clay. No. 15 is without much doubt the equivalent of the limerock over the coal bed at the Neighberger drift. Three-quarters of a mile northeast of the Lake shaft the England shaft was sunk several years ago. It was abandoned for some time but is now being operated. On the Avery land half a mile north of the Neighberger mine an old stripping shows the following sequence:

XVII. Section at Avery Stripping.

		FEET.
6.	Soil (about 730 feet A. T.)	1
5.	Limestone, arenaceous, blue to drab, in flag-like layers, shaly at bottom, more massive at top	3½
4.	Shale, argillaceous, dark	4
3.	Shale, black, fissile	1
2.	Shale, dark, pyritiferous	1⅛
1.	Coal	3½

On the 40-acre tract lying immediately north, the same coal has been mined in several places, all near together. At the most southerly of the openings a thin flag-like rock, similar to that found on the Avery land, lies a few feet above the coal. At the most northerly one, however, no such stratum appears. The coal here is overlain by black shale and this in turn by blue shale. It is possible that the flag-like rock may lie so far above the coal that it was not exposed in the shallow pits, but it does not appear to outcrop anywhere in the northern part of the tract. Where the road crosses the branch, one-fourth of a mile north of the Avery stripping, no rocks are seen that can be correlated, on lithological similarity, with the flaggy, calcareous rock in the stripping. Sandstone blocks occur abundantly in the branch and on the hillside for some distance above the bed of the stream. The same rock, in rather thin layers and interbedded with shale, outcrops in the roadside gullies. The coal at all the mines of this group is considered to be the same, the Avery and England mines being located near the eastern and northern edges of the basin. It dips westward from the Carpenter place, as is shown in the Lake shaft, and southward from the England mine, as is manifest in both the Lake shaft and in the Avery mine. The shale between the coal and limerock thickens northward, as shown in both the Avery and the England mines.

A sandstone ridge, to which reference has been made, extends from south of the Vicker mine (at Bethlehem church) northward to the road crossing Dillon creek, in the northwest quarter of section 19. Northwestward along the road the sandstone next becomes conspicuous in the southeast quarter of section 13 (Tp. 41 N., R. XXVI W.) From this point a series of outcrops occurs along Deer creek northward to near the Owen shaft in the southeast quarter of section 12. There are steep bluffs on both sides of the stream for a portion of this distance. Westward, eastward, northward and southward from this strip, which is not more than 400 yards wide, the more indurated beds graduate into sandy and argillaceous shales. In the Kirk shaft (Tp. 41 N., R. XXVI W., Sec. 13,

Se. qr.) several feet of sandstone are reported, but judging from outcrops in the vicinity and from the topography it must be sandy shale or very friable stone; and less than one-half mile southwest of this mine in the Pitcher shaft only three feet of sandstone are reported, and this is probably the equivalent of the hard calcareo-arenaceous shale overlying the Jordan coal bed in the vicinity of Deepwater and Brownington. The valley of Coal creek along its whole length from Clinton to its mouth is very wide with gradually sloping sides, in strong contrast to the steep bluffs of Deer creek south of the Owen mine. In the broad valley several shafts have been sunk. All of them have passed through soft sandy and argillaceous shales. At the Owen shaft the section is:

XVIII. Record of the Owen Shaft.

		FEET.
4.	Shale, argillaceous, (about 720 feet A. T.)	15
3.	Coal	½
2.	Shale, argillaceous	9
1.	Coal	2

Four inches below the top of the coal bed is a clay parting one and half inches thick. The bed of Deer creek, in the sandstone belt to the south, is cut below the horizon of the seam but no coal is found. About 200 yards northeast of the Owen mine and just east of the range line, the McLeod shaft has been recently put down. The section as seen in the uncribbed shaft is practically the same as that at the Owen shaft, the lower coal corresponding to the lower coal there.

XIX. Section at the McLeod Shaft.

		FEET.
8.	Soil and clay (about 720 feet A. T.)	12
7.	Shale, blue, sandy	4
6.	Shale, black	1
5.	Shale, sandy, yellowish	7
4.	Coal	1
3.	Clay, massive, sandy, micaceous	6½
2.	Shale, black, fissile, and pyritiferous	½
1.	Coal	2

The record of the Kirk shaft (Sec. 13, Se. qr), is as follows:

XX. Record of Kirk Shaft.

		FEET.
4.	Soil and clay, (about 725 A. T.)	10
3.	Sandstone	25
2.	Shale	⅔
1.	Coal	2½

The Jordan shaft and two drill-holes are located a short distance west of the Kirk mine. In each drill-hole, as well as in the shaft about 30 inches of coal were passed through. In the shaft, there were 10 feet of surface clay and soil underlain by 10 feet of what was reported to be the same as the calcareo-arenaceous shale found in the Blair, Diamond and other mines near Deepwater. In the drill-hole, a short distance northwest of the shaft the shale was a little thicker, while east of the shaft it did not appear at all. This only indicates the difference in the disintegration which has gone on at the different places. The shale, as is well shown at Deepwater and Brownington, breaks down upon exposure, to a soft blue material, with the appearance of a blue argillaceous, slightly sandy clay. When not changed by weathering it is a hard, compact, gray rock. Its variation in character from hard gray rock to soft clay is also probably partly due to change in character of the bed as well as to amount of weathering. Three shafts and three drill-holes were put down in the southern part of section 25. The records of all three are nearly the same, varying only in the thicknesses of certain strata. The following is given as the record of one of them:

XXI. Record of Jordan Shaft.

		FEET.
9.	Soil and clay	8
8.	Sandstone, shaly, white and gray	6
7.	Shale, gray, calcareo-arenaceous, with soft shale at top	28
6.	Coal	3
5.	Clay	3
4	Shale, brownish, ocherous, soft	22
3.	Shale, blue, soft	5
2.	Shale, blue	8
1.	Shale, red, white and yellow, with bowlders	24

The seam at the foot of a shaft a few hundred feet south was 30 inches thick, but eastward within 100 yards, it had

thinned to one-half this amount. It rose in that direction six feet within a distance of 300 feet. Westward the coal dipped slightly at about the same angle that it rose eastward and became thicker, some places reaching a thickness of 44 inches. The following section was observed by Broadhead at the Jordan drift in section 25 on Grand river:

XXII. Section at Jordan Drift.

		FEET.
3.	Shale (flagstone), blue, calcareous, weathering to drab, occurring in uniform layers generally about two inches in thickness	15
2.	Coal	2⅝
1.	Shale, blue, with iron ore concretions	9

A shale seam one inch thick is reported about four inches below the top of the coal bed. It likewise occurs in the coal bed in the Jordan shafts. It is also found in the seam at Deepwater and at the North, Owen and Pitcher mines.

The coal, from the McLeod and the Owen mines southward, including that mined in the shafts along the western side to the Calhoun sheet and the eastern side of the Clinton sheet, is is regarded as the same bed. Whether it is the same as the bed at the England and Lake mines to the east is not clear, but the probabilities are that it is not. It is very likely not present where heavy beds of sandstone replace the shales, as along the creek south of the Owen shaft and near Bethlehem church, also northward for a short distance. At least the negative evidence is strong enough to suggest that these areas should be carefully prospected before extended attempts are made to develop the coal.

North of the McLeod shaft, on Deer creek, an exposure occurs within less than half a mile (Tp. 41 N., R. XXVI W., Sec. 12, Ne. qr.). It is as follows:

XXIII. Outcrop on Deer Creek.

		FEET.
12.	Sandstone, thinly bedded, shaly (about 725 feet A. T.)	2
11.	Shale, black, changing to blue above	8
10.	Coal	⅔
9.	Clay	½
8.	Shale, massive, sandy and micaceous	5

		FEET.
7.	Shale, bituminous	½
6.	Coal, Jordan bed, a few inches to	3
5.	Clay, dark	5
4.	Shale, black, fissile	1
3.	Shale, black, pyritiferous	3
2.	Limerock, dark, soft, pyritiferous, bituminous, shaly	1
1.	Coal	3

The details of the lower coal bed are as follows:

XXIV. Details of Lower Coal Bed in Deer Creek.

		INCHES.
5.	Coal	18
4.	Shale, black	1
3.	Coal	4
2.	Shale, black	1
1.	Coal	18

The succession as a whole, the details of the lower bed, and the associated strata of the lower coal, suggest that it is not equialvent to the Jordan coal at the Owen and McLeod mines, but that if any of the coals in this outcrop represent that coal, it is the middle bed, and that this lower bed is equivalent to the Lake, England, and Carpenter seams in the range east.

SECTIONS IN THE NORTH MIDDLE TIER OF TOWNSHIPS.

The townships of the north middle tier compose those in township 42 north, ranges XXIII, XXIV, XXV, and XXVI west. In that part of the eastern township which lies within the area of the sheet sandstones underlie the surface of the northern portion, while in the southern part, except on the tops of the hills, lower Carboniferous limestones are everywhere exposed.

Near the middle of the south line of section 18 there is a 12-inch bed of coal lying at an elevation of about 730 feet A. T., and less than 25 feet beneath it are exposed the limestones of the lower Carboniferous. Over the rest of the area of this township within the sheet and over the eastern part of the township west of it the sandstone of the coal measures has caused a development of topography of the type existing near Gaines. A generalized section of the rocks of township 42 north, range XXIV west is about as follows:

XXV. Generalized Section.

		FEET.
5.	Soil, with large amount of detrital chert in places	5
4.	Limestone, thinly bedded, silicious, apparently graduating southeastwardly into sandstone	8
3.	Shale, soft, argillaceous, bituminous, and probably sandy with some thin sandstone beds and one coal seam, about	50
2.	Sandstone, rather coarse-grained, often massive, with coal beds of small areal extent, from 10 to	60
1.	Limestone (lower carboniferous) exposed	20

The basal sandstone of the coal measures is exposed over the northeastern, eastern and southern parts of the township, except along the principal creeks in the southern part where the lower Carboniferous rocks are well displayed. The shale member and the upper limestone occur only in the western central and northwestern parts of the township and only in the highest land. The flat-topped highland area in this part of the township is made up of these strata and the limestone occurring near the top has, by its resistance to erosion, preserved the flat top of the highland and caused the transition to lower land underlain by the basal sandstone to be abrupt. There is over most of the lowland a soil derived largely from the shale and in many places part of this member still caps the sandstone. The limestone No. 4 is believed to be the equivalent of the basal limestone of the Henrietta formation—the bed lying 8 to 20 feet above the Spangler coal bed of the northwestern part of the sheet. The correlation is based principally upon the relations which exist between the limestone and the underlying coal bed which is essentially the same in both cases; but it should be understood that this correlation is merely suggestive. The basal limestone of the Henrietta beds of the northwestern part of the sheet, when carried over the intervening lowland with its average northwestern dip would lie near the top of the highland southeast of Calhoun. When this is taken in connection with the fact, as is shown farther on, that the Tebo bed thins out not far from the line of the Missouri, Kansas and Texas railroad, and that the next overlying coal above the Tebo bed in the northwestern part of the sheet,

which is well marked by its highly fossiliferous overlying shale bed, cannot be found in the eastern part of the district, it seems reasonable to conclude that the western representative of the coal bed in the highland southeast of Calhoun is the Spangler coal, and that the overlying limestones at the two places are equivalent. This highland is therefore an outlier of the Warrensburg upland of the northwestern part of the sheet.

In section 26, Ne. qr., shaly coal is reported to occur in a well at a distance of 20 feet from the surface, and about 100 rods northwest of this it is said to be 18 feet beneath the surface. The seam has never been mined on account of its shaly character. It lies about 45 feet above the bed of Barker creek, in which loose chert is abundant, though no lower Carboniferous rocks were seen in place nearer than the ford two miles to the north. In the southeastern corner of section 21, at the Journey coal mine, the section is:

XXVI. Section at the Journey Coal Mine.

		FEET.
4.	Shale, sandy, with clay at top (about 725 feet A. T.)	8
3.	Shale, and concretionary iron ore, with irregular lenticular layers of shaly coal	½
2.	Shale, massive, hard, argillaceous (claystone)	1
1.	Coal, with pyrite, irregularly distributed (exposed)	1½

One hundred yards down the branch from this point and a few yards north of the road the coal is overlain by three feet of drab shale. Less than half a mile to the west a drill-hole passed below the level of the bed at the stripping but did not penetrate coal. South of the drill-hole a short distance an 8-inch seam of coal is exposed at about the same elevation as the Journey seam. At the drill-hole and in the banks of the branch sandstone is well exposed. The latter appears westward from the drill-hole for a distance of three-quarters of a mile, and seems to be the principal rock underlying the soil. Between the church, in section 29, and the creek west of it shale becomes abundant. In the creek bank be-

neath the horizon of the shale about 15 feet of sandstone are exposed. Down the creek, sandstone, coarse and rather heavily bedded is the only rock seen until the lower Carboniferous strata appear in the southern part of the section.

In the northeastern part of the township sandstone is found abundantly on the higher land south of Barker creek and in the banks and low bluffs of the same stream. Westward very few exposures of indurated rock occur east of section 16, and those that are found are chiefly shales On the edge of the highland, towards the western part of the township, Norwood found at the Munn coal bank (section 17, Sw. qr.) the following section:

XXVII. Section at the Munn Coal Mine.

		FEET.
6.	Concealed, with scattered pieces of chert containing *Productus muricatus*, *Spirifer planoconvexus* and *Chonetes mesoloba* (about 845 feet A. T.)	17
5.	Limestone, hard, blue and drab, silicious in thin beds, containing *Productus prattenianus* and crinoid stems	2
4.	Concealed	20
3.	Local drift composed of chert, sandstone, etc	5
2.	Clay, ocherous, blue	1½
1.	Coal, upper 5 inches poor and shaly	2⅓

The coal seam lies about 100 feet higher than the bed at the Journey mine, and also above it stratigraphically. The coal at the Journey place is in a shale lens in the basal sandstone of the coal measures as given in the general section of the township. The coal at the Munn mine lies above the sandstone and in the overlying shale bed. The seam at the Journey mine was not known at the time of Norwood's visit to the area. The limestone of the Norwood section caps the small area of highland shown on the topographic map north of where the section is located. On the western side of the area, along the Tebo creek, it is much more silicious, and in places has changed to a calcareous sandstone. A section including the rocks outcropping from the top of the hill (Sec. 8, Sw. qr.) down to Tebo creek half a mile westward and about two miles southeast of Calhoun is about as follows:

XXVIII. Section southeast of Calhoun.

		FEET.
6.	Slope, covered with chert (about 840 feet A. T.)	10
5.	Limestone, argillaceous, silicious	2
4.	Shale, argillaceous, bluish and drab, becoming black near the bottom	20
3.	Coal	2½
2.	Shale	20
1.	Sandstone, about	70

The sandy rock lying near the top of the hill in the northern part of section 21 and adjacent parts of 16 is correlated with the limestone of the above section. The coal bed is not seen along the eastern face of the highland.

The strata of the coal measures of the eastern part of township 42 north, range XXV west, are about the same as those in the western part of the township east. Toward the southeastern corner of the township, as in the southwestern corner of the one east, the sandstone forming the basal member of the coal measures is thinner than farther north. Shales predominate down almost to the level of lower Carboniferous rocks. In the northwestern corner of the township to the east the basal sandstone has a thickness of about 70 feet. Along the eastern side of the township under consideration exposures rarely exceed 45 feet in thickness. The steep banks of the streams in sections 12, 13, 23 and 24 are made up entirely of it. Southward its absence as massive sandstone is shown in the more gently sloping sides of the valleys. As a whole the coal measures of this township differ considerably from those of the last one mentioned. A general section of the rocks in township 42 north, range XXV west, is as follows :

XXIX. Generalized Section.

		FEET.
14.	Limestone, basal member of Henrietta formation	2
13.	Shale, argillaceous	20
12.	Coal	1½
11.	Shale	25
10.	Shale, black, calcareous, fossiliferous	⅔
9.	Coal	1
8.	Shale and clay	10
7.	Limerock, hard, dark blue, one bed	1
6.	Shale, black, fissile, with clay at top	4
5.	Coal (Tebo bed)	2½
4.	Clay and shale	4
3.	Coal (not persistent)	½
2.	Shale and thin sandstone	35
1.	Sandstone	50

The strata above the Tebo coal were not indentified in the township east, nor southeast of the line of the Missouri, Kansas and Texas railroad. Between Lewis and Calhoun the Tebo seam lies as much as 40 feet beneath the surface. Southeast of the railroad the surface remains nearly level for a mile or two. The coal bed does not dip westward at an angle sufficiently great to carry it above the surface within this distance, so that if it did not thin out it would outcrop in some of the ravines, or occur in some of the wells in this part of the area. The limerock associated with the coal bed is a relatively very resistant stratum and would certainly be exposed at some point along the creek. The fact that it does not appear is considered good evidence that it has changed from a resistant limestone to a softer rock.

The Tebo coal was sought by drilling and by sinking a shaft at Calhoun, but it was not found. It is probable, however, that the top of the shaft was below the horizon of the coal, but the top of the drill-hole was certainly above it. A seam of coal 14 inches thick is said to have been reached in a well in section 15, Ne. qr., at a depth of 24 feet This is several feet below the level of the Tebo bed. In a well in section 28, Nw. qr., there were encountered 12 feet of sandstone, 9 feet of gray shale bearing impressions of ferns, and two feet

of coal. The top of the well is 814 feet A. T. This coal bed lies at very nearly the same elevation as the Tebo seam at its nearest outcrop, about two and one-fourth miles due west. But here there is no limestone associated with the seam. No other coal bed or other strata were found near the well that could be correlated with the Tebo coal or its associated rocks. From the fact that at the exposure just referred to it lies several feet lower than the surface of the country eastward and that its rise southeastward is not sufficient to carry it above the surface before reaching the well the most probable conclusion is that the coal and its associated beds change in character in this direction, the limestone overlying the coal passing into sandy shale and the coal finally thinning out. The coal in the well is probably therefore an occurrence of the modified Tebo bed. It is manifest that this is not a northern extension of the Jordan coal of the township to the south, for it lies at a much higher horizon. It is possible, however, to correlate it with the Tebo coal but the latter is clearly not the equivalent of the Jordan coal. It was suggested that the two might be equivalent, and an examination of the outcrops on Deer creek from the Owen shaft on the south to the Missouri, Kansas and Texas railroad, where the Tebo coal is exposed, on the north, was consequently made. The results are contained in the series of connected sections shown in the accompanying sketches (E to B, plate VII). The sections were measured at points along the creek and were arranged in succession as they occur and at their proper relative elevations.

An extremely interesting occurrence of coal in this township is the Lewis, or Mammoth bed, which was extensively mined several years ago. It occurs as a long narrow bed extending from the middle of the east line of section 25 northwestward in a nearly direct line. It is very easily traced on the map by the line of shafts which were sunk to it. The shaft at the extreme northwest is in the northwestern corner of section 17. The coal along the axis of the basin is said to be a little more than 40 inches thick. The trend of the axis is northwest and southeast though not in a perfectly straight line;

the deviations are small. The width of the basin containing coal of workable thickness is about 140 feet, 70 feet to each side of the axis of the basin, the limit of workable thickness being considered two feet. The seam rises in both directions at right angles to the axis of the basin and thins rapidly upon the ascent. The total rise is, on an average, about 1 foot in 5 from the axis. A cross-section of the basin is represented below (figure 12.)

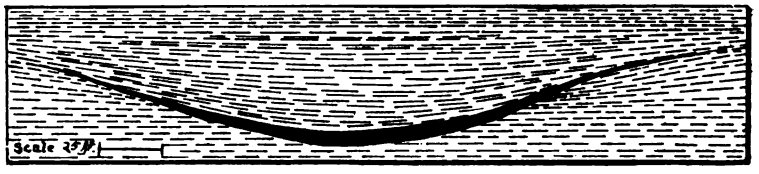


Figure 12. Cross Section of Mammoth Coal Bed.

The section of the Bowen shaft, in section 17, Nw. qr. measured by Dr. J. H. Britts while the exposure was fresh, is as follows:

XXX. Section at Bowen Shaft.

		FEET.
24.	Limestone, with fossils (about 830 feet A. T.)	2
23.	Shale, light drab	1⅔
22.	Limestone, concretionary, with ochre	⅓
21.	Shale, black, massive	2½
20.	Shale, light colored	8
19.	Shale, white, argillaceous	3
18.	Shale, black, bituminous	2
17.	Coal	½
16.	Clay and shale	9
15.	Shale, jointed, bituminous	2
14.	Shale, sandy	12
13.	Limerock, hard, blue	2½
12.	Shale, calcareous, with fossils	3
11.	Shale, bituminous	2
10.	Coal (Tebo bed)	2½
9.	Clay and shale	9
8.	Shale, black	½
7.	Coal, with pyritiferous concretions	3
6.	Shale, sandy, light colored	12
5.	Shale, dark colored, bituminous	7
4.	Coal, extra good quality	½
3.	Shale, bituminous	7
2.	Coal (Mammoth bed)	5¼
1.	Shale, pyritiferous	13

In sections 22, 23 and 24 the strata below the Mammoth coal are sandstones. It is believed that they also occur beneath the bottom of the shaft and the Mammoth seam here is the lowest coal. In the generalized section of the rocks of this township the place of the Mammoth bed is near the base of the shale just above the lower sandstone. The record of the Cooperative shaft at Lewis station (Sec. 9, Sw. qr.) is:

XXXI. Section of Cooperative Shaft at Lewis Station.

		FEET.
17.	Soil and surface clay (about 815 feet A. T	15
16.	Clay	½
15.	Coal	1½
14.	Clay	1
13.	Interval (probably soft argillaceous shales)	82
12.	Shale, black, fissile, calcareous, fossiliferous	2
11.	Coal	1½
10.	Clay	8
9.	Sandstone, hard	5
8.	Shale	4
7.	Limerock, hard, massive	1
6.	Shale, black, fissile, with numerous calcareous concretions	4
5.	Coal (Tebo bed)	2½
4.	Clay	1½
3.	Shale	2⅔
2.	Coal	½
1.	Interval, no coal	27

A ledge of limestone outcrops in the road a few feet above the top of the shaft. For a distance of more than a mile northwest of the shaft sandstone occasionally crops out, and everywhere the soil is sandy, In the northeast corner of section 8 the following is shown:

XXXII. Section Northwest of Cooperative Shaft.

		FFFT.
4.	Concealed, sandy soil from top of hill (about 825 feet A. T)	40
3.	Concealed, abundant limestone fragments, the limestone is shaly at top and carries abundant fossils, *Chonetes mesoloba* and several species of Productus.	8
2.	Shale, black, fissile	1
1.	Shale, argillaceous	4

About 100 yards to the west and at an horizon about 15 feet lower, the strata exposed are:

XXXIII. Outcrop below Section XXXII.

		FEET.
4.	Limestone (about 800 feet A. T.)	4
3.	Limestone, shaly, drab and yellowish, changing to shale in places	3½
2.	Shale, black, fissile	4
1.	Coal	1

The coal in this section is correlated with the upper seam in the Cooperative shaft at Lewis, and the limestone of the section preceding with the limestone outcropping just above the top of the same shaft. The upper two members of the previous section, according to this correlation, are replaced at the shaft by shales. From the fossils contained and from the relation to the Tebo coal bed the limestone in section XXXII is correlated with the fossiliferous limestone outcropping about half a mile west of Huntingdale in the Clinton area. The coal bed just below that limestone is represented in this section by the black shale. The limestones shown in section XXXIII are also correlated with the limestones outcropping only a short distance down the branch west of the outcrop of the coal and limestone near Huntingdale, and the coal seam with the bed outcropping near the ford on Honey creek, about two miles west of Huntingdale. The limestone is the first one above the Tebo coal. Eastward from this locality the rocks outcrop in the succession shown in the Cooperative shaft.

On the railroad northeast of Lewis two shafts are now working in the Tebo coal. The first one, the Tebo mine, located in the Nw. qr. of section 10, passed through the same strata that occur at the Cooperative shaft below the second coal bed. Its surface elevation is less than that of the latter. The second is the Gedney shaft located about one mile beyond the Tebo mine. The succession is:

XXXIV. Section at the Gedney Shaft.

		FEET.
8.	Soil (about 760 feet A. T.)	2
7.	Clay, blue	10
6.	Sandstone	½
5.	Clay	12

4.	Sandstone	1
3.	Shale, light colored	3
2.	Shale, black, fissile	1
1.	Coal	2½

The coal is without question, the Tebo bed. The cap-rock could not be found in an outcrop nearby, possibly on account of the change to a soft rock. This is the most easterly place in the township where this bed has been found.

In the northwestern corner of the township outcrops are few. Topographically this division of the township is a part of the Warrensburg upland, being held up by the relatively resistant limestones of the Henrietta formation. The most important member considered as a topographic determinant is the limestone occuring just above the top of the Cooperative shaft at Lewis and also as a ledge near the top of the Bowen shaft (Section 17, Nw. qr.). The rocks below are well shown in the shaft records. Those above it consist of alternating limestones, sandstones and shales, with a thin bed or two of coal. Along the edge of the upland south and southwest of the shaft in section 17 exposures are infrequent, except of the basal limestone of the Henrietta beds, which is so often seen near the top of the rather faint escarment forming the southeastern edge of the upland.

In Tp. 42 N., R. XXVI W., Sec. 25, Se. qr. occurs the most southerly outcrop of the Tebo coal found within the area of the sheet. This is the outcrop shown in the series of sections on plate VII already referred to as illustrating the relations of the Tebo and the Jordan coals. Northward along that part of this township lying within the sheet, exposures of more than a single ledge in one place are not abundant. A coal bed is worked in the Nw. qr. of section 25. This vein is correlated with the Tebo coal. The locality was not visited and the correlation is based upon the reported thickness of the coal and its elevation.

Farther northward, in sections 1 and 12, there are a few outcrops of limestone, sandstone and shale, but only a few feet in each case. They all belong in the Henrietta formation.

The exact position in the general section of each of these thin strata was not determined for this small area, but by studying the coal measures occurring just west and also those of the same formation north and northwest, the succession may be very well predicted for this small area.

SECTIONS IN THE NORTHERN TIER OF TOWNSHIPS.

The townships under consideration include all those in 43 north, ranges XXIII, XXIV, XXV, and XXVI west. Beginning on the east, sandstones and shales of the coal measures occur. In that part of township 43 north, range XXIII west, lying within the area of the sheet the only rocks exposed are sandstones, with thin beds of shale. No coal has been found.

The rocks of that part of township 43 north, range XXIV west, which lies within the area, with the possible exception of sections 19 and 30, all lie below the horizon of the Tebo coal. The rocks of this township consist of the basal sandstone of the coal measures, with interbedded and lenticular masses of shale. A few occurrences of coal exist, though in each case the beds are of very limited geographic extent. The capping of the surface on the uplands is generally shale of a few feet in thickness, the lower part of the beds just above the basal sandstone. The shale is so soft that it is almost entirely stripped off down to the sandstone, the remnant serving only to fill up inequalities in the surface of the latter and producing a remarkable smooth and nearly level plain. The larger streams are incised from 40 to 70 feet in the basal sandstones and consequently flow in rather steep-sided, though generally wide valleys.

The basal sandstones are exposed in the bluffs of the creek in sections 23 and 24. They occur in rather thick beds with occasional thin layers and small lenses of shale. They are rather coarse-grained, generally reddish in color and often cross-bedded. An outcrop of about two and one-half feet of coal, overlain by several feet of blue, argillaceous shale occurs in the northeastern quarter of section 27. The hillside above the seam is sloping and appears to be made up of soft shale

and thinly bedded sandstone. Coal also crops out in section 22 (Sw. ¼ of Nw. qr.), but the exact thickness could not be determined. This is probably the same bed that is described by Broadhead as occurring on the Dillon place. It is as follows:

XXXV. Section on the Dillon Land.

		FEET.
6.	Sandstone, light brown, mostly soft, with occasional remains of large forms of Sigillaria and Calamites	30
5.	Slope, shale	6
4.	Sandstone, at bottom of interval	2
3.	Coal	2
2.	Shale, sandy	14
1.	Sandstone, in creek, with Lepidodendron, Sigillaria and Cordaites (exposed)	2

In the southwest quarter of section 28 a bed of coal is seen in a small stripping. It lies near the level of Tebo creek bottom. There is another small mine about one mile to the south, a short distance north of the township line in section 33. The coal is 38 inches thick, immediately overlain by two feet of black shale, and that in turn by sandstone. About one-fourth of a mile west, at a locality formerly known as the Neff place, the layers exposed in a shallow pit are:

XXXVI. Outcrop near Neff Place.

		FEET.
5.	Concealed, with fragments of shale and sandstone (about 750 feet A. T.)	15
4.	Coal, thinning out within a few feet northward	½
3.	Clay (shale)	7
2.	Shale, bluish-black	1½
1.	Coal	2

Farther west, but east of Tebo creek, sandstone crops out at short intervals. The eastern bluff of the creek bottom, in section 32, is an almost unbroken escarpment of rather heavily bedded sandstone. Along the railroad in section 29 it is everywhere exposed. The highway crosses the railroad at the southwestern corner of the section in a cut showing six feet of massive, coarse-grained, cross-bedded sandstone. Northward, in section 20, it is exposed in the ravines, but is often shaly. Towards the western side of sections 30 and 31 shale again becomes prominent, though thin sandstones occur in them. Near the middle of the southern part of the north-

west quarter of section 30, at the coal mine operated by Edwards and Minish, the following section is displayed:

XXXVII. Section at Edwards and Minish Mine.

		FEET.
7.	Soil and shale (about 670 feet A. T.)	4
6.	Coal, not persistent	¼
5.	Shale	7
4.	Shale, dark in places, light in others	2½
3.	Coal, in two beds, with thin shale parting	1
2.	Shale, light colored	¾
1.	Coal	3

The lower coal seam lies about 25 feet above the level of the floodplain of Tebo creek, which is 200 yards west of the mine. At the Edwards drill-hole, about 500 feet east of the railroad bridge, in section 31, 28 inches of coal are reported at a depth of 30 feet, but on account of the softness of the rocks overlying the coal no attempt is made to mine it.

Four hundred feet west of the Edwards and Minish mine, a bed of coal 35 inches thick was encountered in a drill-hole at a depth of 32 feet. This lies at about the horizon of the coal at the mine and is supposed to be the same bed. Farther west, some 800 feet, a drill-hole 136 feet deep encountered no coal except an 8-inch seam, 20 feet from the surface. About 500 yards directly south of the drill-hole a shaft was sunk to a depth of 70 feet but no coal was reached. The top of the shaft and of the drill-hole are each about 815 feet A. T. Several drill-holes were put down in the vicinity of the Edwards and Minish mine, but no coal was struck excepting within a short distance west and south of it. In Tp. 43 N., R. XXV W., Sec. 36, Nw. qr., the Edwards shaft was sunk several years ago. The following strata were passed through:

XXXVIII. Section at Edwards Shaft.

		FEET.
9.	Soil, (about 665 feet A. T.)	8
8.	Clay	6
7.	Sandstone	12
6.	Coal	⅝
5.	Clay	1
4.	Shale, argillaceous	20
3.	Shale, black	18
2.	Coal, very soft	8½
1.	Clay (exposed)	1

About one-half mile southwest of the shaft, across the west fork of Tebo creek and near the railroad, a hole 75 feet deep was bored but no coal except a thin bed near the top was encountered. The drill-hole is about 720 feet A. T.

Some years ago Broadhead examined the rocks exposed at Calhoun. The section is along the Missouri, Kansas and Texas railroad from the station eastward:

XXXIX. Section at Calhoun.

		FEET.
12.	Sandstone, brownish	6
11.	Ironstone, red, sandy	1
10.	Sandstone, shaly, light drab, lower 3 feet ocherous	27
9.	Shale, dark	1
8.	Coal, and bituminous shale, former shaly	1
7.	Shale	3
6.	Sandstone, light drab, abounding in Stigmaria	2
5.	Clay	1
4.	Coal, and argillaceous shale	½
3.	Clay, greenish, with brown tinge	3
2.	Coal	1
1.	Clay	2

In the accompanying notes it is stated that "the beds here undulate somewhat. In the first small cut west of the railroad bridge (half a mile east of the station) the Stigmaria sandstone is seen six feet above the railroad track, one foot thick and apparently level; crossing a valley about 400 feet wide to the next cut west, the sandstone is four feet above the track and three feet in thickness, at which place it furnishes a good quarry rock. Fifty feet farther it dips beneath the track and is concealed for 80 feet, when it rises and in a short distance is four feet above the track and apparently level for 600 feet. A short valley here intervenes, beyond which we find the upper members of our section as quoted above."

Excepting a small area in the vicinity of Calhoun and a narrow tongue running a short distance up the creek from the southeastern corner of the sheet, the rocks of township 43 north, range XXV west, are all above the horizon of the Tebo coal. The first appearance of the Tebo seam northwest of Calhoun is in Tp. 43 N., R XXV W., Sec. 23, Se. qr. It was

struck in a dug well at a depth of 40 feet from the surface. The top of the well is about 780 feet A. T. The coal bed is correlated with the Tebo coal on the ground of its reported thickness and of the occurrence of a hard rock above it. It has been mined about one mile west of the well, the seam lying about 750 feet A. T. The exposures along the road from Calhoun to the well are sandstone. In section 22, southeast quarter, an outcrop shows:

XL. Road Outcrop Northwest of Calhoun.

		FEET.
7.	Shale, and coal, decomposed (about 760 feet A. T.)	1
6.	Shale, argillaceous, becoming dark at bottom	10
5.	Limestone (single bed)	1
4.	Shale, argillaceous, calcareous	½
3.	Shale, black, fissile	1
2.	Coal (Tebo bed)	2
1.	Shale and clay	9

About 500 yards up the creek the upper part of this section is well exposed. It is as follows:

XLI. Outcrop on Creek Northwest of Calhoun.

		FEET.
6.	Slope, with shale (about 772 feet A. T.)	10
5.	Shale, black, pyritiferous, calcareous, full of Producti.	1
4.	Shale	½
3.	Coal	1
2.	Clay, passing into argillaceous shale	7
1.	Shale, dark blue	8½

Still farther up the creek the shales at the top of this section are 15 feet thick and are overlain by sandy shale and thinly bedded sandstone. The higher strata in this part of the township are well displayed in an outcrop and a well record in section 28. The former is located on Sand creek northeast of the center of the section.

XLII. Section on Sand Creek.

		FEET.
5.	Sandstone, on slope (about 795 feet A. T.)	10
4.	Limestone, with chert nodules	5
3.	Shale	20
2.	Coal	1
1.	Shale	20

The lower member includes a part of the shale in No. 6 of the preceding section. The well is on the Thornton place and is located at the center of the section. The record as reported is:

XLIII. Record of Thornton Well.

		FEET.
13.	Soil and clay (about 845 feet A. T.)	7
12.	Clay, red, sandy	5
11.	Flint, fragments?	1
10.	Clay, sandy	4
9.	Limestone	1
8.	Shale, red	3 to 4
7.	Limerock, concretionary, "nigger-heads"	1
6.	Shale, hard	3
5.	Limestone, blue, hard	2
4.	Shale, black	2½
3.	Coal	1
2.	Shale, hard, gritty	7
1.	Limestone	1

Between the bottom of the well and the top of section XLII there is an interval of less than 25 feet, which is probably made up principally of sandstone and sandy shale.

A sandstone, apparently the bed at the top of section XLII is well exposed in the ravines of the northeastern corner of section 28 and adjacent parts of section 29. It is a coarse, red, often cross-bedded, massive rock. Its top reaches as high as the top of the Thornton well. Its thickness is 60 feet or more. At the center of section 29 a dug well 36 feet deep reached a hard rock, probably limestone, at the bottom. A thin bed of coal, about eight inches thick occurs in the extreme northeast quarter of section 30. It lies at about the elevation of the bottom of the well at the center of section 29. Loose blocks of limestone lie on the surface above the coal and its associated black shale, the latter being 18 inches thick.

At the Kampe coal mine, in section 20, southwest quarter, the following succession is represented:

XLIV. Section at the Kampe Mine.

		FEET.
7.	Limestone (about 770 feet A. T.)	7
6.	Concealed	5
5.	Limestone	1½

		FEET.
4.	Shale, argillaceous, becoming dark and passing into black fissile shale	5
3.	Shale, argillaceous, blue	3½
2.	Shale, black, fissile	¼
1.	Coal, about	½

From near, if not directly from the top of this section massive cross-bedded sandstone extends to the top of the hill in the southeast corner of section 19. Where the road crosses the ravine at the center of the section an unconformity of the sandstone on the limestone is shown. The former rock has a basal conglomerate of limestone pebbles. On the eastern side of the ravine sandstone reaches from the top of the hill to near the bottom of the ravine, while on the other side the regular limestone and shale of the coal measures are exposed, all the beds lying horizontal. One-half mile farther up the creek from the Kampe coal mine the rocks exposed are:

XLV. Section Northwest of Kampe Mine.

		FEET.
5.	Sandstone, with basal conglomerate visible in places (about 785 feet A. T.)	15
4.	Clay and shale, blue, sometimes cut out by sandstone	12
3.	Limestone, reddish, highly fossiliferous, sometimes cut out by sandstone	½
2.	Coal, shale and clay, sometimes cut out by sandstone	1
1.	Limestone, exposed to bed of creek	2

These strata form a part of the limestones lying 10 to 15 feet above the coal at the Kampe mine. About 1500 feet beyond, on Sand creek, another outcrop occurs, in which the sequence is:

XLVI. Outcrop on Sand Creek.

		FEET.
4.	Limestone shaly (about 790 feet A. T.)	1
3.	Shale, black	1
2.	Limestone	1
1.	Shale, black, fissile, containing large calcareous concretions	3

Coal is said to lie a few feet below the base of this outcrop and to have been mined at one time. It is reported to be about two feet thick. At several places, within a short distance, sandstone is exposed in the bank of the creek, lying on a thin basal conglomerate, the latter resting on limestone in places, and at one point a heavy conglomerate about 15 feet

thick is exposed, made up of limestone, shale, coal and sandstone pebbles and lying at the base of the bluff. It is overlain by 25 to 35 feet of sandstone, upon which rests, in the same outcrop, a bed of limestone. The sandstone soon disappears and regular limestones and shales take its place.

In the rest of this township and that part of Tp. 43 N., R. XXVI W., which lies within the sheet few details are shown. A large number of outcrops of single beds of limestone occur. From these it appears that the section of the small area would consist of two or three limestone beds, three to eight feet in thickness, separated by intervals of shales and soft sandstones and a thin bed or two of coal, the whole making up a thickness of about 70 to 100 feet above the coal at the Kampe mine.

GEOLOGICAL FORMATIONS.

The formations exposed within the area of the sheet, as shown in the table, are five in number and belong to three periods of geologic time. They represent three separate periods of submergence, separated from each other by periods of emergence and subaerial erosion.

ORDOVICIAN.

The lowest formation exposed within the area probably belongs near the base of the Ordovician system. No fossils have been found in that part of it lying within the limits of the sheet or near it, but the same rocks exposed farther southwestward in the state have recently been shown by the fossils occurring in them, to belong to the Calciferous. The exposed thickness of the beds within the Calhoun sheet is about 40 feet. They consist of gray and drab subcrystalline and earthy magnesian limestones and calcareous sandstones carrying chert in masses scattered through the more crystalline varieties and in discontinuous layers between the beds of limestone. The latter are often separated by thin seams of greenish shale which, in the more earthy phase of the formation, often reach several feet in thickness.

The chert is both amorphous or chalcedonic and oolitic. The latter in Missouri is apparently confined to the Ordovician

and Cambrian rocks, since careful search has failed to prove its existence in the Carboniferous. It occurs in beds, usually continuous over a considerable area, while the chalcedonic variety occurs in concretionary masses scattered through the limestone and in thin, nodular, discontinuous seams.

The uppermost member of the Calciferous series within the area of the sheet is generally a limestone, but in two places at least it is a friable, coarse-grained, white or saccharoidal sandstone. The latter is always of very limited geographic extent and appears to have been in small discontinuous patches on the surface of the Ordovician land when it was submerged at the beginning of Carboniferous sedimentation.

CARBONIFEROUS.

Mississippian Series.

Kinderhook Beds. The basal members of the Mississippian series crops out only on Grand river in the southeastern part of area and on the lower part of Tebo creek. Its areal exposure is very small. It consists, within the limits of the sheet, of two members; one, the Chouteau limestone, and the other perhaps the representative of the Louisiana limestone. The third or median subdivision, the Hannibal shale, has not been recognized. The basal member consists of from one to five feet of compact bluish white, fine-grained, thin-bedded limestone, with a few thin seams of greenish shale between the beds. It contains abundant pyrite collected in spots, scattered through the bed, which weather out leaving the surface of the rock roughened by the small cavities and stained by iron oxide. It graduates upward into the shaly bed of the next division without any sharp line between. It contains very few fossils.

The limestone regarded as the Chouteau includes about 10 feet of shaly, argillaceous beds. The following fossils have been identified:

Syringopora harveyi, White,
Syringothyris extenuatus (Hall).
Spirifer biplicatus, Hall.
Athyris hannibalensis (Swallow).
Productella pyxidata? (Hall).
Plectambonites rhomboidalis (Wilckens), var.

None of these forms are abundant. Crinoid stems occur but they are all of small size and are not very abundant.

Augusta Limestone. The formation as represented within the limits of the area includes both the lower and upper Burlington limestones.

The Lower Burlington consists of about 30 feet of bluish to drab, fine-grained, compact limestone, carrying abundant chert in nodules and in thin beds between the strata. The latter are thin and irregular. They become earthy toward the bottom and grade imperceptibly into the Chouteau. At the top there is a rather abrupt transition to the overlying beds. Fossils are not abundant. Crinoid stems occur in the limestone but they are small. These beds appear to belong to the upper part of the typical Lower Burlington, as exposed at Sedalia and in Boone county, the lowest part being absent.

The Upper Burlington beds, within the district, are grayish or whitish, coarse-grained, encrinital limestones, in rather massive beds, carrrying some chert, all of which occurs in discontinuous layers between the limestone strata. These rocks are highly fossiliferous. From the lower 15 feet the following forms are obtained.

Zaphrentis dalei, Edwards and Haime.
Zaphrentis tenella, Miller.
Physetocrinus ventricosus (Hall).
Spirifer grimesi, Hall.
Spirifer forbesi, Norwood and Pratten.
Straparollus latus (Hall).

Higher up there occur:

Orthis swallowi, Hall.
Productus burlingtonensis, Hall.
Chonetes illinoisensis, Worthen.
Streptorhynchus crenistria (Phillips).
Athyris incrassatus, Hall.
Straparollus roberti (White).
Capulus equilateralis, (Hall.)
Pleurotomaria montezuma, Worthen.
Igoceras pabulocrinus, (Owen.)
Granatocrinus norwoodi (Owen and Shumard).
Schizoblastus sayi, Owen and Shumard.
Amplexus fragilis, White and St. John.

The upper sub-division of the Augusta formation, the Keokuk, does not occur. Loose chert carrying Keokuk fossils and

even those of higher horizons of the Mississippian series occurs scattered over the surface on the tops of the hills. The drill-hole at the Clinton artesian well passed through about 30 feet of chert at the top of the Mississippian rocks, which probably belongs at the top of the Burlington. The higher formations of the series once existed, but were removed through erosion before the coal measures were deposited.

Des Moines Series (Coal Measures.)

Cherokee Shales. The lowest strata of coal measures within the area of the sheet are grouped together. They consist principally of sandstones and shales with impure limerock of small geopraphic extent and generally only a foot or two in thickness.

The base of the subdivision is everywhere a coarse and very ferruginous sandstone. In places the iron oxide is so abundant that attempts have been made to mine it. The beds in the vicinity of Brownington are the most ferruginous of any within the area. Occasionally the basal beds pass into a conglomerate the pebbles of which are chert and the matrix sand with ferruginous cement. These layers graduate upward into shale, the thickness of the sandstone being very variable. In the extreme eastern part of the area it is apparently only a very few feet thick; a coal bed, underlain and overlain by shale, lying within 15 or 20 feet of the Mississippian limestones. Along Deer creek, south of the Owen coal shaft, the sandstone is apparently 15 feet thick. The higher beds are not altogether shales, but the latter alternate with thin beds of sandstone.

The limerock lenses in this formation are usually associated with beds of coal. They are always impure, dark in color and carry abundant fossils. The most extensive of these is the one associated with the coal at the England, Avery and Lake mines. The most abundant fossils occuring in it are the following:

Spirifer cameratus, Morton.
Spirifer perplexus, McChesney.
Productus muricatus, Norwood and Pratten.
Productus costatus, Sowerby.

Productus splendens, Norwood and Pratten.
Productus nebrascensis, Owen.
Streptorhynchus crenistria (Phillips).
Lingula, sp. und.
Pecten (large).
Sphærodoma primogenia (Conrad).
Pleurotomaria broadheadi, White.

Plant remains are found in the sandstones and shales in the southwestern corner of the area, especially in the latter. Fully 25 genera and nearly 100 species are represented. The shales associated with the Jordan coal bed are famous for the abundance and excellent state of preservation of these fossils.

The only limestone of wide distribution occurring in this subdivision within the area of the sheet is that associated with the Tebo coal bed. Its eastern boundary is shown on the topographic map, and its character and thickness is described elsewhere. The geographic distribution of the formation is shown on the physiographic sketch (figure 9) it being coextensive with the area of the Nevada lowland. It probably extends southwest beyond the limits of the state, and possesses hydraulic properties.

Henrietta Beds. The rocks which go to make up this formation consist of limestones, shales and sandstones with a predominance of shales. Limestone is important, though the beds are not so thick here as they are further westward along the same horizon. Sandstone is poorly represented. One bed, more or less shaly, lies near the base of the formation in the northern part of the sheet. Its thickness is less than 25 feet. The areal extent is coextensive with the Warrensburg upland (figure 9).

PLEISTOCENE.

The superficial material consists of soil and alluvium with probably a thin deposit corresponding to the loess of the Missouri river counties. The alluvium is confined to narrow belts along the principal streams. There are two benches, representing two periods of formation here as elsewhere in this part of the state.

GEOLOGICAL STRUCTURE.

GENERAL CONSIDERATIONS.

Within the area of the Calhoun sheet there are three sets of rocks, the result of three periods of deposition, separated from one another by unconformities which represent two periods of subaerial erosion.

The two lower systems dip northwestward at about the same angle. Within the Calhoun area they are conformable with each other from a structural point of view. The period of erosion which intervened between the times of their deposition was one of slight crustal movement unaccompained by deformation of the strata. The sediments are all open-sea deposits and were probably nearly horizontal when laid down. The present northwestward dip is due to a subsequent tilting of the strata in that direction.

The upper rocks, excepting the basal beds, lie almost horizontally. They have, however, a slight northwestward dip, the strike running approximately parallel to that of the underlying rocks but the angle of dip is less. There is therefore a true unconformity between these beds and those of the other two sets. This is due partly to conditions of sedimentation and partly to subsequent crustal movements. The beds were deposited on a northward or northwestward sloping floor of the sea and consequently had an inclination corresponding closely to the slant of the surface on which they were laid down. Subsequent warping of the strata of the Mississippi valley whereby there was a greater elevation to the westward, gradually dying out eastward has made the dip less. The eastern border of this series of rocks is near the boundary between two centers of movement, one uplifting the Ozark dome which increased the original westward dip of the rocks; the other, the fading eastward extension of the uprising of the Rocky mountains and the great plains, tilting the latter eastward and inverting the original westward drainage. Both movements are probably of recent geologic date.

GEOLOGICAL CROSS-SECTIONS.

The cross-sections shown on plate VII illustrate features of the geology of the area which are difficult to make clear in any other way. Each is located on the topographic map. In section A, B, C, the relations of the upper rocks on the eastern and western sides of the sheet are represented. It shows the thinning out, eastward, of the Tebo coal seam and its associated rocks and the replacement of these, in the east, by sandstone. There is also brought out the fact that in an easterly advancing sea the higher deposits retain their off-shore character farther in that direction than the lower ones.

Section D, E, F illustrates the relation of the Tebo and higher coals of the northern part of the sheet to the Jordan coal and others of similar character of the southern part. The upper rocks are of more uniform thickness and character over considerable areas. The lower ones change rapidly owing to the varying conditions prevailing during deposition.

By section G, H, K, L, the lower Carboniferous strata of the southern part of the area and the basal beds of the coal measures are represented in their typical development.

UNCONFORMITIES.

By unconformity, as here used, is meant the relation of two sets of strata one overlying the other, the lower one, however, having been elevated, subjected to erosion and again submerged before the upper one was deposited upon it. The strata of the two series may or may not be discordant, depending upon the deformation to which the lower set was subjected before the upper had been deposited. Considered in this light there are two unconformities within the area. In the first one, that between the lower Carboniferous and Ordovician rocks, there is no marked discordance between the strata, or it is so slight that it does not show plainly in a small area.

The Ordovician land was apparently an almost dead level plain lying near sea level. The submergence was wide-spread so that large areas went under water at once. The sea ad-

vanced rapidly and no characteristic shore line deposits were formed. The first beds were open-sea deposits and were laid down horizontally upon the flat sea-bottom.

The unconformity of the coal measures upon the lower Carboniferous manifestly represents a marked erosional period, but in the submergence of the latter rocks the basal beds of the former lie in a different attitude upon the strata beneath. The advance of the sea over the lower Carboniferous land inaugurating the deposition of the coal measures was gradual. The lower Carboniferous land was higher and the depression was apparently not so wide-spread. It commenced somewhere northwest of the area under consideration and progressed eastward, the sea advancing slowly.

COAL DEPOSITS.

THE COAL BEDS OPERATED.

Henry county has been an important coal producer for many years. Its mining industry began with the competion of the Missouri, Kansas and Texas railroad. At first, the center of the industry was at Lewis station. For many years this was one of the most important coal-mining localities in the state. It remained so until the "Big Coal," or Mammoth bed, the narrow belt of thick coal which crossed the railway here, was exhausted, or had become too deep or too far from the railroad to be worked profitably. Immediately afterwards operations began on the next overlying bed, the Tebo seam. Work on this bed has continued uninterruptedly since, though not on such an extensive scale as before.

With the building of the Kansas City, Clinton and Springfield and the Kansas City, Osceola and Southern railroads, in the early part of the last decade, the bulk of the mining industry was transferred to the southern part of the county. The Jordan coal bed, the most important coal deposit of the county, soon attracted a large amount of capital. Before the building of the railroads very little mining had been done in this bed on account of the lack of transportation facilities.

The Missouri, Kansas and Texas railroad does not tap the areas underlain by this bed of coal. The coal mining industry of this district has been improved by the location within it of two large clay-manufacturing establishments, which consume considerable quantities of fuel. The rest of the output of the mines is shipped to Kansas City and intermediate points. The character of the coal, its geological occurrence, its geographical distribution and the facilities for marketing it combine to make the region in which it occurs an important mining center.

GEOGRAPHICAL DISTRIBUTION OF THE COAL BEDS.

The principal workable coal deposits of the Calhoun area occur in two separate fields in different parts of the district. In addition to these two rather large areas, there are a great number of small basins and local deposits which are mined in a desultory way for the local use.

One of these areas, and the most important one from the point of view of present development, lies in the southwestern corner of the sheet. It is part of the area underlain by the Tebo coal bed, the rest lying in the southeastern corner of the Clinton district. Within the area of the Calhoun sheet this field includes the mines between Deepwater and Brownington, those east of North switch and those running northward from the latter in a narrowing belt up the valleys of Coal and Deer creeks. Within this area might also be included the mines located on Sparrowfoot creek: the England, Lake, Neighberger and Avery.

The eastern border of the Jordan coal basin enters the Calhoun district near Brownington and runs northward, including the mine on the Goff land, thence northward between Sparrowfoot and Deer creeks, up to the latitude of Clinton, where it thins out. The bed is not continuous over the area included within the sheet west of this line though it is very nearly so. Some outliers may also occur east of the line.

The other area of workable coal covers a large part of the northwestern part of the sheet. It is the extension of the Tebo coal belt of the Clinton area, but here it covers practi-

cally all the northwestern corner of the sheet. Its southeastern border coincides with the line of the Missouri, Kansas and Texas railroad. This area has not been developed so extensively as the southwestern one, partly on account of the character and thickness of the coal and partly owing to lack of transportation facilities. There are no means of shipping coal from this area except from a narrow strip adjacent to the railroad on the southeast border. This area includes two persistent coal beds both of which, under favorable circumstances, may be worked.

In addition to these, there are doubtless many pockets and small basins similar to those occurring in many places over the eastern part of the area. The "Big Coal" at Lewis station was not mined out, but was followed northwestward into this area and abandoned on account of its increased depth and the distance from the railway.

VERTICAL DISTRIBUTION OF THE COAL BEDS.

The Jordan coal bed is geologically the lowest within the area, or at least it is lower than either of the beds in the northwestern part of the district. Some of the small isolated basins and pockets may be lower but the probabilities are that they are not. They are probably very nearly on the same horizon, but separated from the Jordan seam and from each other by inequalities in the floor on which they rest. The Jordan coal lies only a very few feet above the outcrop of the lower Carboniferous limestones and in the southern part of its basin it is the lowest coal in the productive series.

The next bed above the Jordan coal is the Tebo bed. The vertical distance between the two beds is 50 to 100 feet. The former does not extend beneath the area covered by the latter and in many places the whole thickness of the coal measures beneath the Tebo coal seems to be no more than 100 feet.

Above the Tebo seam, the next bed is the Honey Creek coal. It is unimportant at present as a coal-producer, and will probably never be otherwise on account of the thinness of the bed. The vertical distance between the Tebo and Honey

Creek seams is about 50 feet. This is the highest bed within the district which is thick enough to mine. There is another bed or two above this, but they are only a few inches in thickness.

MINING IN THE JORDAN COAL SEAM.

The Thompson mine is located one mile west of Browningtton, and is connected with the Kansas City, Osceola and Southern railroad by a long switch. It is 40 feet deep, and is equipped with steam-hoisting machinery. The coal seam is about 3 feet thick, the details of which are given in the annexed cut (figure 13). About twenty-five men are employed. The coal is partly consumed by the locomotives on the railroad and the rest is shipped to Kansas City and intermediate points.

Figure 13. Details of Coal Bed at Thompson Shaft.

The Dunlap and the Stevens mines are located a few hundred feet north of the Thompson shaft. The same bed of coal is worked. Both are drifts. They were opened out from strip pits, after the amount of overlying material became to thick too be taken off economically, and after the shales were strong enough to form a safe roof. About fifteen men are employed.

The shaft of the Central coal company, formerly known as the Keith and Perry mine, is located just on the west line of the Calhoun sheet. The same coal bed is worked as at the Thompson. It is 60 feet deep and is equipped with good machinery. About seventy-five men are employed. The details of the coal bed are the same as at the Thompson shaft. The mine is connected with the Kansas City, Clinton and Springfield railroad by a switch. The output is consumed at points along the line of the railway and at Kansas City. It has been in operation for several years and is one of the best equipped and best managed mines in the state.

The Sheardon mine is one mile west of Brownington, just south of the southwestern corner of the sheet. It is 40 feet deep and equipped with horse-power hoisting apparatus. About twenty men are employed. The coal is shipped over the Kansas City, Osceola and Southern railway to local points. The North Clinton shaft, formerly the Woods and North mine, is located a short distance east of North station on the Kansas City, Clinton and Springfield railway (Tp. 41 N., R. XXVI W., Sec. 23, Sw. qr.) It is connected by a switch with the railway and is equipped with steam-hoisting machinery. During the past two or three years the mine has not been worked continuously, and the output has been small. The details of the coal bed are the same here as at Deepwater and Brownington.

An analysis of coal from the old Jordan mine near this shaft, made by Chauvenet, showed:

	PER CENT.
Water	8.47
Volatile matter	42.18
Fixed carbon	45.35
Ash	8.50

Near Grand river east of North station is the Herring and Hess mine, probably operating in the Jordan coal. No work is done during the summer. Three men are employed during the winter. Three miles southeast of Clinton are the Owen and the McLeod shafts, on adjoining tracts of land. The same bed of coal is worked in both, and the section at one place is the same as that at the other. The following is the section at the Owen shaft:

Details of Coal Bed at the Owen Shaft.

		INCHES.
5.	Shale, argillaceous, calcareous	12
4.	Coal (top bench)	4
3.	Clay parting	½
2.	Coal (bottom bench)	19
1.	Clay	12

An analysis of this coal, by Chauvenet, shows:

	TOP.	MIDDLE.
Water	8.30	7.14
Volatile matter	38.66	36.95
Fixed carbon	48.35	48.65
Ash	5.85	6.10

This shaft is 25 feet deep, and is operated by horse-power. The output is hauled to Clinton and is used for steam and domestic purposes. Only three or four men are employed. The McLeod shaft is also 25 feet deep and has horse-power hoisting machinery.

OPERATIONS IN THE TEBO COAL BED.

The Tebo coal bed is the next higher bed above the Jordan seam, that is continuous over a considerable area. While the area underlain by it, within the Calhoun sheet is, but little, if any, larger than that underlain by the Jordan coal, yet the total known area of the former is much greater than that of the latter. It lies at a varying height above the horizon of the Jordan coal though the average for the area under consideration is not far from 70 feet. Its thickness is not so great as the average of the Jordan bed, though it is much more regular, and the bedding is more even. It is closely associated with a limestone showing the prevalence of open sea conditions soon after, and presumably during its deposition.

The mines operating in the Tebo coal are all located in the northern part of the area, and the principal openings are situated on the Missouri, Kansas and Texas railroad. The coal is very uniform in thickness in all the mines. It is overlain generally by about 3 feet of shale, and that in turn by a limestone, forming a good roof. The thickness of the seam, together with that of the overlying shale, is sufficient to give room for good, high entries. The detailed section of the coal bed fails to show any persistent slate band, but there are rather numerous pyritiferous masses of shale of small size and lenticular or irregular shape scattered through the bed. These are so abundant in places that they have to be picked out in order not to interfere with the sale of the product.

The Co-operative mine at Lewis station is a shaft 75 feet deep, equipped with steam-hoisting apparatus, and connected with the Missouri, Kansas and Texas railroad by a switch. The coal is 28 inches thick. About twenty-five men are employed.

The product of the mine is consumed at various points along the railroad, the principal place being Sedalia.

An analysis of this coal, made by Robertson, shows:

	PER CENT.
Moisture	5.99
Volatile matter	37.76
Fixed carbon	48.19
Ash	9.06

One-half mile north of the Co-operative shaft is the Pigg mine, operating in the same bed of coal. It is a drift opened on the outcrop of the seam in the south bank of Tebo creek. The location is about three-fourths of a mile from the railroad, but its product is taken to the cars for shipment over a tramway operated by horse-power. A section of the coal bed, and the associated layers, is shown in the cut below: (figure 14).

Inches.
Limestone, "cap rock"....18
Shale, arenaceous and pyritiferous, gray 18
Shale, black, fissile.....20
Coal, with 1 to 2-inch pyrite band near middle...80
Clay, dark, hard.....6
Fire clay white ("mining").....10

Figure 14. Section of Coal Bed at the Pigg Drift.

The Tebo shaft, in the same seam, is about 1½ miles north of Lewis station. It is located on the railroad. It is 35 feet deep, and is equipped with steam-hoisting machinery. About fifteen men are employed. The coal bed has about the same character and thickness here as at the Co-operative shaft.

At the Calhoun mine, formerly known as the Gedney shaft, the Tebo coal is also mined. It is located on the railroad 1 mile northeast of the Tebo mine. The shaft is 30 feet deep. Hoisting is done by steam. The product is partly consumed by locomotives, and partly shipped to Sedalia and local points. About twenty men are employed.

The Tebo coal is mined in two or three small strippings on Tebo creek and its branches west of Calhoun. None of them are worked continuously. They are opened to supply local demands

MINES OPERATING IN THE HONEY CREEK COAL SEAM.

The Honey Creek coal is the next bed above the Tebo that is mined. Between it and the latter is a thin bed, but it has never been operated at any place within the limits of Henry county. The Honey Creek coal lies about 50 feet above the Tebo bed. It is usually a little more than 1 foot in thickness, occasionally reaching 18 inches. It is of excellent quality and favorably located for mining, but it is usually too thin to compete with the thicker beds near it.

There are three small mines within the area which are operating in this seam. None of them are worked continuously. In each only two or three men are employed during the winter.

The McElwrath mine is near Lewis station. It is a drift run on the outcrop of the coal bed. The section at the mouth of the drift is:

Section at McElwrath Drift.

		FEET.
3.	Shale	10
2.	Coal	1½
1.	Clay	2

At a drift about 1 mile northwest of Lewis station, which is operated on the same coal bed, the section showed:

Section at Drift Northwest of Lewis.

		FEET.
4.	Limestone, shelly	3½
3.	Shale, black	4
2.	Coal	1
1.	Clay	1

The Watkins mine, located on the highland 2½ miles southeast of Calhoun, is operated occasionally during the winter. The succession of layers here is essentially the same as at the McElwrath mine excepting that the coal is thicker, measuring about 2 feet.

MINES OPENED IN MINOR COAL BEDS.

There are several small mines in the southern part of the area operating in seams of coal which cannot be correlated with any of the beds having any considerable areal extent. They are all considered to be small lenticular beds deposited in local depressions.

At the present time coal is being mined by drifting on the outcrop of the bed at the base of a bluff on the eastern side of Deer creek valley, one-fourth of a mile north of the McLeod shaft. The coal seam is overlain by a bed, more or less continuous, of bituminous, fossiliferous limerock, which occurs often in concretions. The detailed section of the seam is said to be as follows:

Details of Coal Bed at Drift north of McLeod Shaft.

		INCHES
5.	Coal (top bench)	16
4	Shale (parting)	1
3.	Coal (middle bench)	4
2.	Shale (parting)	1
1.	Coal (bottom bench)	18

The product of this mine, as well as that from the McLeod mine, is consumed at Clinton, and in the neighborhood of the mine. Both mines are worked during the fall and winter only.

The Stockton mine is on the Avery land, about 4 miles southeast of Clinton. It is worked during the winter only. The bed is 2 feet thick.

The England drift is on the adjoining 40-acre tract on the north. It is worked during the winter. It is opened on the outcrop of the coal.

The Neighberger mine is on the same section, and one-half mile south of the Stockton mine. It is also a drift worked at intervals by two or three men. The section is as follows:

Section at Neighberger Drift.

		FEET.
3.	Limerock	3
2.	Shale, argillaceous, dark	1-6
1.	Coal	3

One-half mile to the west is the Lake shaft, which has not been operated for several years. The coal in the four mines last mentioned is probably the same bed. It may also be the same as in the mine on Deer creek. If so it lies below the Jordan seam.

The Henry shaft is one mile south of the Neighberger mine. It is 20 feet deep, sunk through 16 feet of soft shale, and 3 feet of coal. It is worked by two or three men at in-

tervals to supply the local demands. It is probably operating in the Jordan seam.

The Gehart mine is worked during the greater part of the year. It is an open pit. The product is consumed in the vicinity. The section is shown in figure 16:

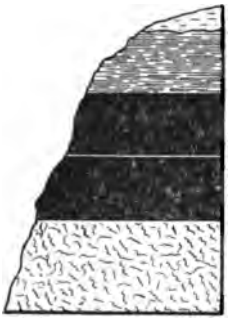


Figure 16. Section at Gehart Pit.

The Duckworth mine is located 2 miles southwest of Gaines post-office. It is a stripping and is operated only during the fall and winter. It is working in the lowest seam of the coal measures, probably the equivalent of the Jordan coal. The Journey stripping is located 6 miles southeast of Calhoun. It is worked by one or two men at intervals, to satisfy the local demands. It is also on the lowest bed of the coal measures. The equivalent of the same bed is worked in section 36 (Tp. 41 N., R. XXIV W.) in a stripping. It lies only a few feet above the lower Carboniferous rocks.

The Edwards and Minish mine is operated in an isolated basin of coal about one mile north of Calhoun. It is worked by stripping and also by drifting. The product is consumed at Calhoun. The section is given in figure 17. The whole area underlain by this bed of coal as proved by drilling is very small. The shale overlying is soft, making it somewhat difficult to mine the coal excepting in open pits.

Figure 17. Section of Coal Bed at Edwards and Minish.

The Lewis lens of coal, the "big coal" of Henry county 20 years ago, has already been described as a belt of coal of lenticular cross-section, appearing to

be a filled valley of erosion. Several years ago it was an important source of good coal. At the thickest part of the bed it reached 5 feet. The belt was so narrow and worked upon it was prosecuted so vigorously that it was soon exhausted. The only operations at present in this bed are at three or four small strippings located 2½ miles southeast of Lewis station.

Figure 15. Section of Coal Seam at the Evans Mine.

The above is the section exposed (figure 15).

CLAY DEPOSITS.

(BY H. A. WHEELER.)

EXTENT AND CHARACTER.

The clay deposits of Henry county are among the most important in the whole state and form the foundation of an extensive industry. The latter, however, is located in great part within the limits of the adjoining sheet. That part of it in the area under consideration is situated chiefly at the town of Calhoun where pottery is manufactured.

The beds from which the best clay is obtained are members of the coal measures. Many of the shales occuring with the sandstones of the formation make excellent material for brick, tile and pottery. Many of the deposits have already been located and described in connection with the other sections of the coal measures. In the Lake shaft, about three and one-half miles southeast of Clinton there is an extensive four-foot bed of potters clay, at a depth of only seven feet; and another one of about the same thickness at a depth of about 40 feet. The shales overlying the Jordan coal at the Dunlap and the Stevens strippings one mile east of Deepwater are on the same horizon as the shales which are used at the latter place so extensively for sewerpipe. That the deposits are equally extensive within the Calhoun area is shown by the exposures which are numerous.

The shales and underclays of the coal seams afford an abundance of good material for making good structural and paving-brick, sewer-pipe and draintile. While none of them have ever been utilized, and while good clay occurs abundantly near the surface where it can be obtained very easily, it is probable that most of these clays will not be used for some time. One of the underclay seams, the one worked at Calhoun, is a good fireclay and answers admirably for all ordinary refractory purposes, as it withstands a temperature of 2,500°F.

The residual clays of the area are used for making ordinary building brick. They are also well adapted for making draintile. The supply of good clays for nearly all purposes is practically inexhaustible, and the easy access should greatly encourage the development of the deposits. No better locations are found in the state.

POTTERS' CLAY.

The most extensive deposits of potters' clay yet developed in the entire state exist within the Calhoun area. At the present time the mining of clay is carried on most actively at Calhoun, where are situated several potteries. Large quantities of the raw clay are also shipped. The annual production is about 5000 tons, of which nearly two-thirds is sent into southwest Missouri and into Kansas.

CALHOUN.

This locality is the largest producter of potters' clay in Missouri. A persistent seam of the clay, ranging from 3 to 4 feet in thickness, is found near the tops of the hills near the town. The amount of stripping necessary is usually moderate so that it can be cheaply mined. It is a safe, easy-working and reliable clay.

The results of a careful examination of the deposits and the analyses made of them, together with the notes, are given below. The sample collected to represent the district was an equal mixture of clay from the Jegglin and from the Hardin pits. It had the following physical characteristics:

Color dark gray, with slight yellow to brown iron stains. Texture massive, compact, uniform and very fine-grained. Taste lean and very finely gritty. Slacked rather readily to one-fortieth to one-tenth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 16.5 per cent of water it made a plastic paste that shrunk 5.5 per cent in drying and 2.2 per cent when vitrified, giving a total shrinkage of 7.7 per cent. Briquettes of the air-dried mud gave an average tensile strength of 150, and a maximum of 168 pounds to the square inch. Incipient vitrification occurred at 2,100°F., complete at 2,300°, and viscous above 2,500°. It dried rapidly, but required slow heating to avoid checking. It burned to a compact, gray to buff body when vitrified.

An analysis gave the following results:

	PER CENT.
Silica	71.94
Alumina	17.60
Water	5.27
Sesquioxide of iron	2.35
Lime	0.62
Magnesia	0.56
Alkalies	1.51
Total	99.85
Total fluxing impurities	5.05
Specific gravity	2.84

Jegglin Clay Pit. About one-fourth mile north of Calhoun is the Jegglin bank of clay from which about 1,500 tons a year are shipped. It has been operated for 12 years on a royalty of 20 cents a ton, and the clay is shipped to the Jegglin potteries at Boonville and Calhoun. The clay is an admirable stoneware clay, as it takes a salt glaze well, stands rapid drying, gives a light colored ware and is very safe working. The following is the section exposed at this bank:

Section at the Jegglin Clay Pit.

		FEET.
7.	Soil	1
6.	Clay, yellow	4
5.	Shale, greenish gray, soft, and fat	2
4.	Sandstone, red, soft, coarse-grained	1
3.	Shale, red to black, soft, fat	½
2.	Clay, potters'	4
1.	Sandstone, shaly, yellow, coarse-grained, (exposed)	1

The potters' clay is hard and massive when freshly mined, seeming to be rock rather than clay; but on exposure to the weather it slacks completely into a soft plastic mass. It is very sandy and lean, and dark gray in color. There are occasional yellow streaks of iron along the joint planes especially where there is no overlying shale. The over-burden is stripped off from the clay, which is then loosened by blasting, and hauled in wagons to the railroad, which is about one-fourth of a mile distant, for shipping. The clay lies about level or with very slight roll.

Littlepage Clay Bank. This pit is situated one-half mile north of Calhoun, and one-fourth mile northwest of the old Jegglin pit, of which it is undoubtedly a continuation. The clay is similar to that in the Jegglin bank, and it is shipped to the potteries in the southwestern portion of the state, to the extent of 1,000 to 1,200 tons annually. The following is a section at this bank:

Section at the Littlepage Clay Pit.

		FEET.
7.	Soil	1
6.	Clay, red, sandstone and gravel	2
5.	Sandstone, gray, coarse-grained, friable	1½
4.	Sandstone, intermixed with shale	4
3.	Shale, drab to green, soft, fat, rich in iron concretions	3
2.	Sandstone, very ferruginous	½
1.	Clay, potters'	3

Hardins Bank is three-fourths of a mile north of the town. The clay is overlain by a thin seam of red sandstone that merges into iron ore. About 500 feet south of the pit there is a lean ore that will assay 35.0 to 40.0 per cent of iron. This is the same seam as exposed at the Jegglin bank, through the lower portion is so sandy that it is not mined. The following is a section.

Section at the Hardins Clay Bank.

		FEET.
6.	Soil, sandy	1
5.	Clay, brown, joint	2
4.	Clay, gray to brown	1
3.	Sandstone, ferruginous	1
2.	Clay, potters'	3
1.	Sandstone, yellow, shaly (exposed)	1

Little Clay Bank. About one mile north of Calhoun is the Little bank, which was opened in 1889. It produces about 1,000 tons of clay a year, which is shipped to southwest Missouri, and as far as Fort Scott, Kansas. The clay is similar to that in the Jegglin bank of which it is an extension. The following is a section:

Section at the Little Clay Pit.

		FEET.
5.	Soil	1
4.	Clay, brown to gray	1
3.	Clay, gray (weathered shale)	2
2.	Iron ore, sandy (with hematite)	½
1.	Clay, potters'	3½

The clay also outcrops on the southeastern edge of several hills, and occurs in the crest of a north and south ridge.

Mullin Clay Pit. One-fourth mile east of Calhoun is a clay bank which has only been a small producer, with a total output to date of perhaps 500 tons. The upper portion of the potters' clay seam at this point is rather fat, dark colored and fine-grained, while the lower portion is very sandy, hard and light gray in color.

LEWIS.

At Lewis station, on the Missouri, Kansas and Texas railroad (Tp. 42 N., R. XXV W., Sec. 9, Sw. qr.), the following section is shown at the Good coal mine:

Section at Good Coal Mine.

		FEET.
18.	Limestone, yellow, impure	3
17.	Shale, sandy	6
16.	Shale, black, laminated, with iron-stained concretions	2
15.	Shale, light and dark	8
14.	Coal	1½
13.	Fireclay	2½
12.	Shale, sandy	7
11.	Sandstone, fine-grained	2½
10.	Shale and sandstone	20
9.	Shale, black	2½
8.	Sandstone	2
7.	Shale, black	4
6.	Coal	1½
5.	Shale, sandy, light-colored	9
4.	Limerock, hydraulic	1
3.	Shale, black	1½
2.	Coal	3½
1.	Clay, potters'	2 to 3

The potters' clay mentioned at the base of the above section is probably the same seam as that worked at Calhoun and Clinton and is an excellent quality for stoneware.

SHALES.

The shales of the coal measures are admirably adapted for making paving-brick, sewer-pipe and building brick. The beds are continuous with and fully as extensive as those of the adjoining Clinton district, where they are so extensively developed. In fact the principal places at which the shales are worked on a large scale are just outside of the limits of the Calhoun area. As indicative of the characteristics of these shales the following results are given of a careful examination of the material as exposed at the pit of the Missouri Clay company situated between Deepwater and Brownington. The section is:

Section of the Missouri Clay Pit.

10.	Soil	1
9.	Loess	6
8.	Clay, jointed, brown to gray	6
7.	Clay, gray	2
6.	Shale, yellow, sandy, coarsely laminated	5
5.	Coal	1½
4.	Clay, potter's, olive to buff, shaly	8
3.	Sandstone, soft, gray, argillaceous	2
2.	Shale, soft, gray, fat	6
1.	Shale, black	5

The shale No. 2 was sampled and gave the following results: Color bluish to light gray, with abundant yellow to brown iron stains. Texture finely laminated, and sandy in streaks. Taste somewhat lean, and occasionally gritty. Slacked slowly but almost completely into granules one-eighth to one-fourth of an inch in size. Pyrite was not noticeable; mica scales were present in small amounts. When ground to 20-mesh and mixed with 21.0 per cent of water it made a plastic paste that shrunk 5.7 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 9.7 per cent. The dried mud had an average tensile strength of 124, and a maximum

of 140 pounds to the square inch. Incipient vitrification occurred at 1,800°F., complete at 2,000°, and viscous above 2,200°. It dried rapidly and heated without cracking, and burned to a compact, strong, dark red body. It is well adapted for paving-brick, sewer-pipe and terra cotta.

A chemical analysis gave the following results:

	PER CENT.
Silica	68.54
Alumina	18.49
Combined water	4.62
Iron sesquioxide	3.88
Lime	1.03
Magnesia	0.88
Alkalies	2.37
Total	99.25
Total fluxing impurities	7.76
Specific gravity	2.32

On the Kirk land (Tp. 41 N., R. XXVI W., Sec. 24, Ne. qr.) a bed of blue shale 33 feet thick occurs at a depth of 25 feet. On the Forman place (Tp. 42 N., R. XXV W., Sec. 32) is the following section:

Section on the Forman Land.

		FEET.
7.	Soil	3
6.	Fragments of sandstone and fossiliferous limestone	2
5.	Shale, blue, argillaceous, gritless, grades upward into a soft, whitish, very plastic clay, probably a result of decomposition. It carries, near the top a bed of ochre and concretionary limonite, which varies in thickness from 4 to 12 inches	4
4.	Coal	½
3.	Clay, sandy, pyritiferous, seam of silicious iron ore at the top	1
2.	Shale, argillaceous, black, soft, pyritiferous	?
1.	Clay, plastic, potters' (exposed)	1

BRICK-CLAYS.

Besides the shale which can be used for the manufacture of ordinary brick there is an abundance of alluvial clays that are suitable for this purpose. As yet they are used at only one point, the town of Calhoun, where one yard is in operation. It supplies not only the town but all the neighborhood.

FIRECLAYS.

There is little demand for refractory products as yet from the Calhoun district and consequently little development of

the clays suitable for this purpose. There are abundant good clays suitable. The underclays of the coal seams, which in other parts of the state are often not adapted on account of their yielding at low temperatures, in the Calhoun area are capable of resisting very high degrees of heat, or 2,300° to 2,500° F., the usual minimum limits for refractory wares.

CLAY INDUSTRY.

The clay industry of the area is centered at Calhoun. The clay is mined in the neighborhood and manufactured into stoneware and brick. Clay is also mined for shipment and for use at local factories elsewhere. It is shipped to Clinton, Boonville, Carthage and Deerfield, Missouri, and to Ft. Scott, Kansas.

There are five potteries in Calhoun, one operated by steam power and four by horse power. The combined product in 1894 was 525,000 gallons of stoneware. Sixty men are employed. The ware is of excellent quality and finds ready sale.

There is also one brick yard at Calhoun at which eight men are employed. About 300,000 brick were manufactured in 1894.

BUILDING STONES.

The building stone industry has not been developed. The only local demand for stone of any kind has been for rough foundations, cellar walls and chimneys.

The stones used for these purposes over the greater part of the district are the coal measure limestones and sandstones. The thin sandstone beds interbedded with the lower part of the coal measure shales often furnish a stone just thick enough to be easily quarried and handled.

The limestone capping the Tebo coal makes an excellent foundation stone. It is easily quarried, is just thick enough to be easily handled and is very durable when not exposed to heavy freezing, when it is liable to fracture into conchoidal blocks. It is too dark to make a beautiful architectural stone and is not abundant enough to become of much importance.

It is merely a convenient stone for local use for foundations, cellars and chimneys.

The Burlington limestones of the southeastern corner of the sheet are probably the most valuable building stones within the area but as yet it has not been quarried. The fact, however, that it belongs to the same formation and is of the same character and appearance as the rock in some of the best quarries of the state makes it reasonably certain that it would be equally valuable if quarried.

LIME.

The Burlington limestone of the Calhoun sheet is well suited to be burned into a white lime of the best quality. There is probably no better rock for this purpose in the state. It is easily quarried, abundant, favorably located for kilns, is easily burned and has an abundance of fuel near at hand; but very little has been used for this purpose.

The limestone overlying the Tebo coal has long been considered, from its character, to be a good material for manufacture into hydraulic cement but it is not extensive enough to base a large industry upon. The other rocks of the coal measures of the area are too impure to afford a white lime of good grade.

SANDS.

Sands suitable for building purposes, excepting that obtained by crushing the sandstones of the coal measures are not abundant. There are no glacial deposits as in the more northern districts of the state, which furnish excellent material of this kind. Sand beds do not exist at all in the bed of Grand river. What is carried into it by the streams from the sandstone areas is mixed with a great deal of clay from the softer beds making a mud deposit which lines the channel. The same is true to a considerable extent with regard to the other creeks of the area. Tebo creek has some beds which do not carry as much clay as those in Grand river, yet it has too much to allow the sand to be utilized.

The sandstones of the coal measures when crushed furnish a coarse red sand that is used to some extent.

ROAD MATERIALS.

Within the area of the sheet there is an abundance of good road material. It is of three kinds: Stone, gravel and clay.

Stone. The limestone beds of the lower Carboniferous rocks of the southern part of the area constitute an inexhaustable supply of good material for macadam. It occurs in steep high bluffs along Grand river and Tebo creek where it could be quarried very cheaply. The various limestone beds of the coal measures of the area afford a very good stone for maccadam also. The beds are not thick so that to get a large amount would necessitate working over a large area of country, but on the other hand they occur on the prairie where the facilities for easy transportation are good. The bed overlying the Tebo coal is excellent for the same purpose. That lying about 20 feet above the Spangler coal is also good. While of not so good a quality as the Tebo bed, it occurs in a much heavier bed, making the cost of obtaining it less.

Gravel. Good gravel is not abundant within the area. It occurs in small beds on the tributaries of Grand river in the southeastern corner of the area, within the limits occupied by the lower Carboniferous rocks. The beds on the river contain too large a proportion of silt brought down from the soft shales of the coal measures to make them valuable for road-making.

Burnt Clay. Within the last few years some railways in the state have adopted the use of burned clay for ballasting. It is also well adapted for highway purposes. Of the gumbo clays from which it is made the Calhoun area has a great abundance. The alluvial deposits of the creek bottoms furnish large supplies. In addition the shale beds of the coal measures can also be used. The old dumps around coal mines supply large quantities of clay which has been thoroughly burnt and each mine would supply sufficient material for the roads for a considerable distance in all directions. In localities

where burnt clay has been properly used for roads it has given good satisfaction. It packs well, does not become plastic and forms a hard smooth surface. The use of this material is probably the solution for good roads when stone and gravel are not to be had cheaply.

WATER SUPPLY.

Wells. The natural water supply of the area is drawn from three sources: wells, springs and surface streams. The greater part of the supply for domestic purposes is derived from wells. While the shale beds are generally impervious, there exist in them thin sandy layers at frequent intervals which are generally water-bearing. Abundant supplies of good wholesome water are usually found at a depth of less than 40 feet. In the areas of lower Carboniferous rocks the wells, are, as a rule, deeper. Many of them, however, reach only to the bottom of the residual cherty clay where water is usually found on the surface of the solid rock. The well water of the area generally carries a considerable percentage of carbonate of lime in solution. This is especially true of the wells located in the lower Carboniferous rocks and those in the shales and limestones of the coal measures. The wells in the sandstone belt of coal measures carry a much smaller percentage of lime. These, however, often have a small percentage of iron. One of these, the Jordan well, is located three miles southeast of Clinton (Tp. 41 N., R. XXV W., Sec. 18, Sw. qr.). The water is a weak chalybeate. It comes from the basal sandstones of the coal measures which are here overlain by several feet of shales. The weak flow is due to the fact that the sandstones come to the surface a few miles east of the area at about the same level as the top of the well.

Springs. From an economic point of view springs are of little importance. A considerable number are scattered over the area but they are all small and the greater part of them are not used. Within the area of the coal measures they occur frequently as simply marshy places at the outcrops of an impervious bed of shale. As a rule they cease to flow in the

summer and autumn. Many of the wells of the county are dug in these places. The water is generally unpalatable from the amount of iron. In the limestone area of the southern and southeastern parts of the sheet a fews prings occur. The area of these rocks within the sheet is too small to collect much water.

There are three springs within the area which have some note as mineral springs. The waters from them belong to the chalybeate group of mineral waters. The Peeler spring is about one-half mile southeast of Gaines postoffice, on Pretty Bob creek (Tp. 40 N., R. XXV W., Sec. 2, Se. qr.). It flows out at the foot of a bluff of coal measure sandstone. It is directly at the juncture between the lower Carboniferous limestone and the coal measures. The water has a slight alkaline taste and forms a slight deposit of iron in its channel. The flow is rather weak.

The Sand Creek spring is situated on a branch of Sand creek four miles north of Lewis station (Tp. 43 N., R. XXV W., Sec. 28, Sw. qr.). It is found in a picturesque valley with sandstone bluffs on either side. There are here two springs emerging from the sandstone, but the one sampled is more important on account of its greater flow (perhaps between 50 and 100 gallons an hour). The iron contained in the water is rapidly oxidized and is found in the spring and along its course as a brown sediment. It often forms on the surface of the spring as an irridescent scum which is frequently mistaken for oil. The water is said never to freeze, even in the coldest weather. An analysis of the water by Woodward is as follows:

Analysis of Water of Sand Creek Spring.

	GRAINS IN GALLON.	GRAINS IN LITER.
Silica (SiO_2)	1.0748	0.0184
Alumina (Al_2O_3)	0.0934	0.0016
Ferric oxide (Fe_2O_3)	0.1233	0.0021
Lime (CaO)	3.7499	0.0642
Potassa (K_2O)	2 9789	0.0510
Sulphur trioxide (SO_3)	1.1624	0 0199
Chlorine (Cl)	0.2862	0 0049
Carbon dioxide (CO_2)	10.6656	0.1826
Water in combination (H_2O)	2.1816	0.0374

Oxygen (O)	23 8982	0.4091
Mineral matter	0.0642	0.0011
	23.8290	0.4060
Fixed residue	16.8146	0.2793
Specific gravity		1 0000

United as follows:

	GRAINS IN GALLON.
Silica (SiO_2)	1 0748
Alumnia (Al_2O_3)	0.0934
Ferrous bicarbonate ($FeH_2(CO_3)_2$)	0 2743
Calcium bicarbonate ($CaH_2(CO_3)_2$)	10.8479
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	5.7564
Potassium bicarbonate ($KH(CO_3)$)	2.6541
Potassium sulphate (K_2SO_4)	2.5360
Potassium chloride (KCl)	0.5798
Mineral matter	23.8167
Oxygen for Fe O	0.0123

Streams. The greater part of the area is well supplied with water of very good quality from the streams. The supply from Grand river is abundant and never failing. In periods of protracted drouth the water becomes slightly muddy but there is always enough current to keep it from becoming stagnant. The whole of the northern and northeastern parts of the area are supplied by Tebo creek and its numerous branches. Since it drains an area of limestones and sandstones with a relatively small proportion of shales its water is clear and its bed sandy rather than muddy. The western part of the sheet is well supplied by several creeks.

SOILS.

The soils of the area are, as a whole, fairly productive. Nearly the whole area is capable of cultivation. The soils are both residuary and transported, the former constituting by far the larger portion. They cover the whole area excepting a small strip of alluvial land adjacent to the streams. In the area of the adjoining Clinton sheet there appears to be a thin deposit of transported material extending over the lower portions of the upland adjacent to the larger streams. It is, perhaps, the equivalent of the loess along the Missouri river. Nothing of this kind is noticed along the Grand river within the Calhoun sheet, though the area over which the water might

have spread at the time of the deposition of the loess was so small and the slopes so steep that not much room for deposition was given and less chance for its being preserved on the steep slopes. There is no sign of it along the middle course of Tebo creek.

The alluvial soils necessarily contain the same ingredients as the residuary soils since they were derived from the same beds as the latter and differ from them only in being a more complete mixture of the various constituents of rocks of the area than could be effected without the aid of water. The transported soils are not, therefore, foreign soils, and even if it should be proved that there is a deposit that corresponds to the loess there is not much probability of any necessity of calling it foreign, since the probabilities are that it was derived from the rocks of the Grand river drainage basin and not from the product of the glacial mill. The alluvial (transported) soils are, when well drained, very productive, yet on account of their limited area they are of little importance.

The residuary soils are the result of the decompositon of the rocks in place. It is not to be inferred, however, that even here the various elements of the rocks of the area are not more or less mixed together. The soil now covering an area of sandstones is not solely the result of the decomposition of sandstone, but owing to the slow but constant creep of the soils it is tolerably well mixed with mat erials from higher areas and further, the present soil is the result of the wasting away of probably many feet of rock that originally overlay the rocks now lying beneath the soil. These may have been of widely different composition both from the present county rock as well as among themselves. The soil, therefore, of an area may be considered to contain material derived from many different kinds of rocks, although it is a so-called residuary soil. Residuary soils are, however, generally characterized by a predominance of the elements of the rock on which they lie. A large part of the residuary soil of the Calhoun area is sandy. It is easily tilled and gives a fair return for the labor spent. In some places, where shales are the underlying country rock,

the soil is too close and heavy to make a first-rate soil for tillage but excellent grass is grown. The surface relief is sufficient to give good surface drainage and with care these can be made good soils. The covering of the highlands of the northwestern part of the sheet contains a considerable proportion of lime in its composition. They are good grain and grass producers, and respond liberally to fertilizers.

FORESTRY.

A large part of the area was, at the time of early settlement, a smooth prairie. Luxurient grasses grew six feet or more in height. When these became dry in the autumn they burned with such fierceness that no young timber could gain a foothold. Along the streams where the land was more rugged and where greater dampness prevailed the fires were less destructive. These strips furnished about the only places where timber grew. In some localities not in the creek bottoms where the land was too rugged or the soil not of the kind to grow such luxuriant grasses, trees started but these areas where small. At present the timber is confined to the neighborhood of the creek bottoms or to areas of land unfit for cultivation. Around the head-waters of Tebo creek are oak groves of considerable size, but the trees are all small. A large part of them have grown up since the settlement of the county.

Nearly the whole area over which lower Carboniferous rocks are exposed at the surface is covered with young oak. It is too small to be valuable for lumber. Originally there were some large trees in this part of the area but they have been nearly all cut out. In Grand river bottom there are some large sycamores and elms. In the bottoms of the small streams in the prairie are some cottonwoods, though they are not abundant.

On the cherty hills adjacent to Grand river, black oak is the predominate growth; a few scattered white oaks and post-oaks occur, with here and there a few red oaks on the hillsides where there is an accumulation of soil in cool damp places.

On the very sandy or cherty soils of the prairies near the base of the coal measures are occasional groups of black jack-oak, with now and then a solitary tree scattered over the fields. On the prairies where the soil is less sandy and more fertile an occasional elm occurs.

The principal trees and shrubs of the area are: Black oak, black jack-oak, burr oak, white oak, red oak, post-oak, pin-oak, maple, hickory, cottonwood, ash, hackberry, walnut, cherry, sycamore, box elder, plum, haw, sassafras, sumac, buckeye, locust, red-bud and willow.

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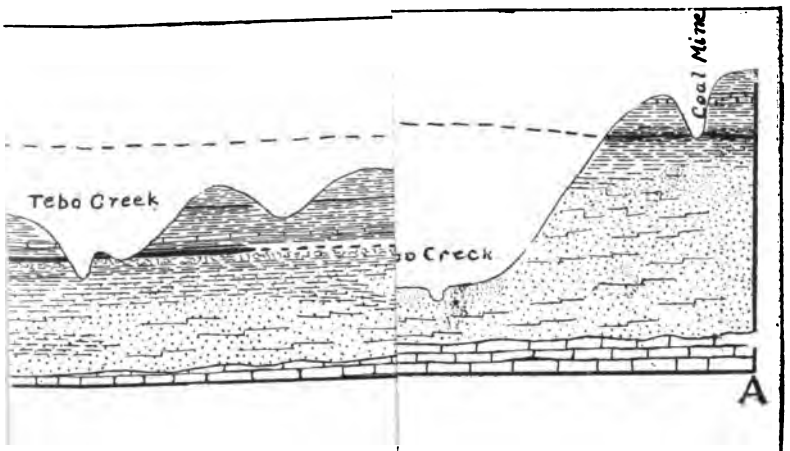
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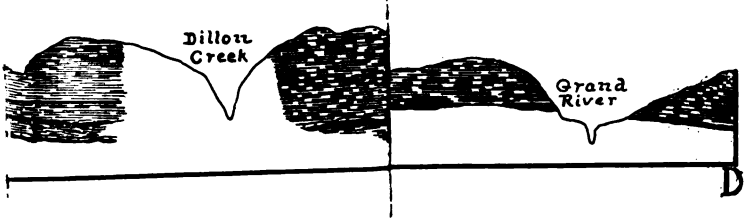
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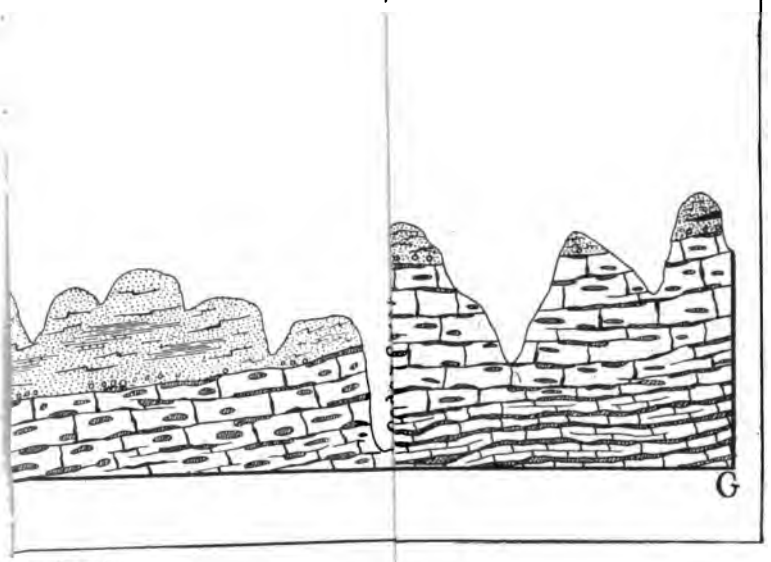
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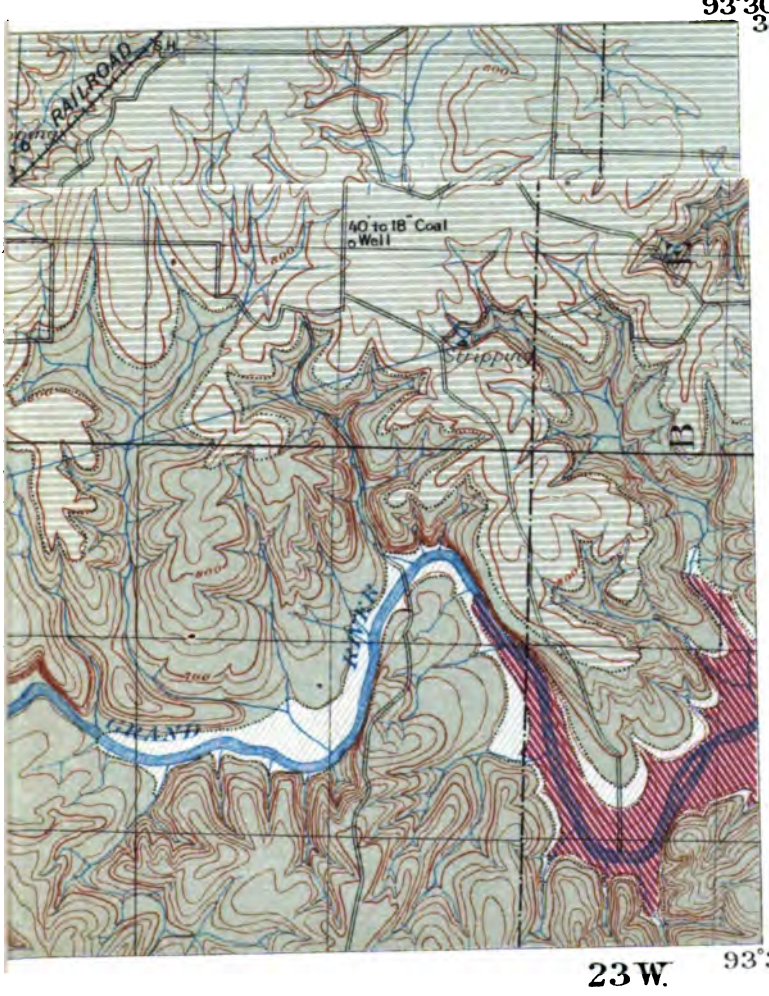
Quadrangle.

CALHOUN SHEET



CONVENTIONAL MARKS

op	Shaft	Geological Boundary	S.H. School House
	D.H. Churn Drill Hole	Building	Sh Shale
	L.S. Limestone	Ch Church	S.S. Sandstone

GEOLOGICAL DESCRIPTION

OF THE

LEXINGTON SHEET.

GEOLOGY OF THE LEXINGTON SHEET.

BY CURTIS FLETCHER MARBUT.

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INTRODUCTION.

AREA AND LOCATION.

The area covered by the Lexington sheet lies in Lafayette and Ray counties, and is named from the city of Lexington, the county seat of the former, and the largest town of the district. The area covered is quadrilateral in shape, being 15′ extent in latitude and longitude, and embracing about 231 square miles. It is bounded by the lines 38° 45′ and 39° north latitude, and 93° 45′ and 94° longitude west of Greenwich.

Its position in the state is northwestern. The Missouri river flows eastward through the northern part of the area, its wide floodplain being a very prominent topographic feature, as well as an important economic one. Its relations to the county lines are shown in the accompanying sketch (figure 18.)

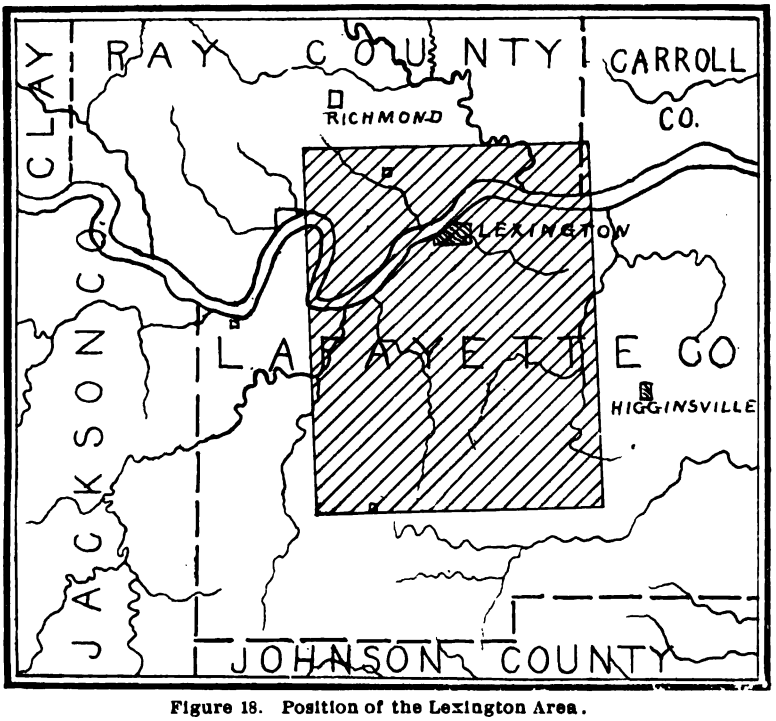


Figure 18. Position of the Lexington Area.

All that part of the area lying south of the Missouri river is in Lafayette county; the rest is in Ray. The southern side of the sheet is about 6 miles north of the southern boundary of the first named county. Its western boundary about 5 miles east of the Jackson county line, its northern boundary is in the southern part of Ray county and is the same as the southern boundary of the Richmond sheet; while its eastern boundary, which is also the western boundary of the Higginsville sheet, runs north and south near the middle of Lafayette county.

FORMER WORK WITHIN THE AREA.

Lafayette county has been frequently visited in the past. Swallow, in 1855, made up his general section of the coal measures of Missouri from studies made principally along the Missouri river, and Lafayette county received a considerable share of attention. In the description of this section the beds occuring in the county are located with precision. In the account of the iron ores and coal fields, issued in 1875, considerable attention is given by Broadhead to the geology of Lafayette county and particularly to the vicinity of Lexington. He published a general section of the rocks of the county compiled by Norwood. Most of the measurements of the rocks above the Lexington coal were made at Lexington. He also published a section from the top of Graddy knob to the small creek one mile north of that locality. Sections on Graham branch, in the bluff near the foot of Pine street in Lexington, and also one at Wellington were noted.

PHYSIOGRAPHY.

GENERAL FEATURES OF THE REGION.

Topographic types are functions of geological relations. Regions of identical, or similar, structural and stratigraphical relations are characterized by identical physiographic types. They are uniform over regions, however large, of the same geological structure and relation of hard and soft beds. They are independent of political boundaries and often have

no essential relation to drainage. Features caused by the latter are functions of the time element. Physiographic types are wholly independent of this factor and hence do not include the idea of development. They are the result of fixed relations and not of the stages in development. All types pass through their various stages in development, but each preserves its separate individuality as a type, though its minor features change. Type features as well as stage characteristics may arise from the same initial feature—the physiographic zero, corresponding to the universal energy in the realm of organic life. Topographic types are the result of the action of constructive forces, while stages express the progress reached in the action of destructive forces. The former express a relation fixed for a given region for a given time, while the latter refers to a constantly changing relation.

The topography of the greater part of the Mississippi valley is of a single type. The region is characterized by one kind of geological structure and hence one type of topography. The accent varies, but the type character underlies it all. It is the step-and-platform, or, as Hill has recently named it, the *cuesta* type and consists of more or less parallel belts of lowland and upland of a particular type traversing the country in the direction of the strike of the rocks. The uplands are characterized by one long gradual slope and one short steep one. The long slope corresponds to the dip of the rocks and usually conforms to the upper surface of a hard bed. The steep slope or escarpment is the abruptly broken edge of a hard bed and the underlying beds which are protected by it. The lowland belts graduate imperceptibly upward on one hand into the upland and on the other are sharply limited by the escarpmented edge of the adjacent highland belt. In structure the type is like a stairway, though the platforms do not always lie level, but may slope downward toward the successive escarpments, so that the tops of adjacent steps or escarpments may be on the same level, or in fact, a step caused by a higher rock geologically may be lower topographically. The ascent may be reversed.

The topography of western and northwestern Missouri is of the type just described. It is developed on the upper Carboniferous rocks, all of which have essentially the same structure. The rocks consist of alternating harder and softer strata which dip slightly northwestward. The soft beds are worn out into lowlands, and the hard ones are left in relief, as uplands. The uplands are terminated eastward by abrupt descents, or escarpments descending to adjacent lowlands, and westward they lie nearly level or decline slightly to the next adjacent lowland. In this part of Missouri the successive platforms are nearly horizontal so that the lowlands are nearly as high above sea level as the adjacent uplands are at their eastern side. Since, however, the drainage is eastward all the lowlands occupy about the same relation to the grades of the streams draining them. While they become higher westward in an absolute sense, they do not become so in a relative sense. They are all typical lowlands in the sense that they are nearly down to grade, while none of the adjacent uplands have reached that stage of their development.

The successive belts of lowland and upland determined by the Upper Carboniferous rocks of western and northwestern Missouri are, commencing with the lowest geologically, the Nevada lowland, the Warrensburg platform, consisting of a narrow belt of upland which may be called the Leeton upland, and a broad extensive belt of rolling country nearly down to grade, which may be appropriately termed the Holden lowland, since it is typically developed in the neighborhood of that town, in Johnson and Cass counties. This is succeeded westward by the Lathrop upland, and this in turn by the Maryville lowland. The lowlands are etched on the shales and sandstones of this succession of rocks and the uplands are supported by the more resistant limestone beds.

LOCAL PHYSIOGRAPHICAL CHARACTERS.

The area covered by the Lexington sheet is traversed by two of the belts described; the Holden lowland and the Lathrop upland. The former includes the greater part of the dis-

trict, while the latter is represented by outliers, detatched by erosion, from the main mass of the upland existing farther to the west. The distribution of the physiographic belts is shown in the subjoined cut (figure 19).

Figure 19. Physiographic Belts of the Lexington Area.

Holden Lowland. That part of the area included in this belt has a rolling surface varying slightly in details of relief but dominated by gentle slopes and wide, open, flat-bottomed valleys. Its variations in detail are more fully appreciated and better understood when it is viewed from the standpoint of its development. Its area was originally occupied by the Lathrop upland. The latter has been driven westward, excepting some large outliers, by the general erosion of the rocks which support it, and this lowland has been developed on the soft shales which underlie the hard limestones. Where the stripping of the limestone has occurred recently the shales still stand well above grade. They form a strongly rolling topography in such cases, though not an angular one. This phase is found in a narrow border surrounding the outliers of the upland. Gradually the surface decends to the gently undulating character of the lowland as a whole. The extremes of local relief are about 100 feet.

The belt is traversed by the wide floodplain of the Missouri river. On account of the size of the stream its grade is lower than that of the smaller streams. This causes the topography of a fringe along the river bluffs to appear young. It extends a little more than 100 feet above the floodplain, and the ravines are narrow, V-shaped and deep. This is local only and is not typical of the whole plain. This effect is heightened also by the recent action of the river. It has been cutting the southern bluffs for a long period, and has, so to speak, advanced inland into the plain. If the river should leave the southern side of its floodplain the bluffs would soon be graded down to gentle slopes. The river is advancing into the plain by cutting the southern bluffs backward so rapidly that the time relation expressed by the topography of the bluffs at these places is not the same as that expressed by the topography of the region as a whole. The height of the bluffs near the mouths of the creeks and on the divides may be compared to the cliffs in bays, and headlands on a receding coast-line. The bluffs in the vicinity of Wellington are less than 100 feet high. Northeastward, toward Lexington, where the Tabo-Sniabar divide is trun-

cated, they are nearly 200 feet high. From this point eastward they decrease in height, and at the eastern limit of the sheet they are again only about 100 feet in height. The high ridge at Lexington is a part of the plain from which the upland limestone capping has been very recently removed. The shales have not yet ben worn down. This belt of lowland extends southwestward through Cass, Johnson and Bates counties into Kansas and northeastward, through Ray, Carroll, Livingston, Grundy and Mercer counties, into Iowa. In the northern part of the state and in southern Iowa its features are obscured by heavy accumulations of glacial materials.

The Holden lowland had practically reached its present stage of development before glacial times. During this epoch its features were slightly modified by the deposition of the loess. It partly filled up the valleys and ravines making a more even surface. Since that time the streams have cut valleys in this material but have not yet entirely re-opened their old valleys. There is no case known of a deflection of a stream by this deposit. The deep narrow ravines along the river bluffs are partly due to this cause. The loess is a thicker deposit along the bluffs than elsewhere.

Lathrop Upland. This feature is represented in the Lexington district by a few isolated outliers. A narrow ridge extends from Odessa northward. Two miles north of the town it forks, one prong extending northward along the west side of Little Sniabar creek a distance of about seven miles from Odessa. A mile north of Greenton it gives off a branch which extends eastward about two and one-half miles, and ends on the west side of the creek. The other prong extends northeastward about four miles from Odessa, and then turns northward on the Tabo-Sniabar divide. It is not continuous like the western prong but is represented by a string of scattered knobs rising sharply above the undulating lowland. The most northerly one of the knobs which still retains its capping of resistant limestone, is about one mile south of Lexington. A small outlier occurs at Mayview and another one three miles south of Wellington. These areas all have flat, plateau like

tops, and steep upper slopes with gradual lower ones. They are typical of their kind. They are of the same type of relief as the "mounds" of Bates and Vernon counties in Missouri, and the mesas of the Far West. Their slopes are typical escarpments caused by the outcrop, near the top, of a resistant stratum underlain by softer beds. The latter weather out rapidly and the resistant one breaks off in blocks, leaving vertical faces.

The upland, until a very recent time geologically covered all of the western part, and probably the whole of the sheet. This is made certain by the numerous outliers not yet consumed. The area is still being constantly diminished by the recession of the edge, or escarpment. It is already cut entirely across in three places by small streams and almost across in at least one other place. At Odessa, a small stream commences on the Holden lowland plain just west of the town and flows northwestward, through a deep notch in the mesa-like ridge, into Sniabar creek beyond. Another branch of the Sniabar, about two and one-half miles north of Greenton does the same. A small branch of Little Sniabar rises near the line of the Chicago, Alton and St. Louis railroad three miles east of Odessa and flows northward through a deep narrow canon in the ridge. The surface of the country around its source is nearly 100 feet lower than the top of the walls of its gorge. These are undoubtedly due to inheritence from an original course, taken by these streams when the surface around their present sources was as high as, or a little higher than, that where the gorges are now. By the combined action of these streams and others originating in the same vicinity the country has been worn down more rapidly here than farther downstream, where the upland still exists. The streams had an existence before the lowland plain existed. They have been able to maintain at least this much of their courses during all the time that has elapsed. It is probable that some of their original upper branches have been captured by streams flowing in the opposite direction.

DRAINAGE.

The area lies wholly within the drainage basin of the Missouri river, most of the surface waters reaching that stream directly within the limits of the sheet. The Missouri river flows across the northern part of the area. Its course and width are shown on the map. It was formerly an important artery of commerce but since the building of railroads it has almost entirely lost its importance in that respect. The navigation was always difficult and somewhat hazardous on account of the ever-changing sandbars within the channel. The navigable channel during one trip, might on the next one, be filled with sand. The current is swift and a large amount of sand is being continually carried. It is loaded to its utmost capacity. Its water is always muddy and dark. Its course in its flood-plain is irregular and is continually changing, but it never develops a series of symmetrical meanders similar to those on the lower Mississippi river. It is difficult to determine whether or not the Missouri river is now more obstructed by sandbars than during the days of steamboat navigation upon it.

The decline in steamboat navigation is largely due to railway competition and the necessity for greater rapidity of transit. But that this is the only cause is improbable. Steamboating still flourishes on the Mississippi and Ohio rivers, not as it did forty years ago but it is still an important factor in transportation, while on the Missouri river it is no longer of any importance whatever. Navigation never was easy on this stream. Running aground on a sandbar was a frequent occurrence, even in the best days of Missouri river boating. But at that time when there was no more rapid means of transit such delays were considered as matters of course. Old river men say that the river is becoming wider and shallower, that bars are becoming more numerous, and that the channel is being filled up. This does not seem entirely improbable. The surface deposits along both sides of the river from Dakota to its mouth and extending backward from it for several miles is a soft, easily eroded material. Until the country was occupied

by an agricultural population this material was protected by a heavy growth of timber, or of grass. That protection has largely been removed within the last 30 years and in addition to this it has been plowed up, thereby making erosion much more effective. Every heavy rain carries a great load of this material and dumps it into the already over-loaded river. It does not seem improbable that the channel is temporarily choked by this sudden increase of load.

The evidence that a similar fate is overtaking the smaller streams of the Lexington area and adjacent districts is abundant and conclusive. Reliable men state that within their own time the larger creeks of this part of the state were clear streams flowing in clean channels of clay or country rock with pools of clear water containing fish which frequent clear brooks. These creeks now have channels completely lined with thick deposits of mud, the water in all is muddy and heavily loaded with fine sediment. Formerly these small creeks continued to flow the year around. Now, during the spring rains they are often overflowing their channels and during the summer and autumn months they either cease to flow altogether or the channel contains a string of shallow, muddy pools connected by a tiny rill of running water. During this period of low water the carrying capacity is zero, yet considerable amounts of detritus are dumped into the channel during every rain shower.

The other streams of the area are small and only a few miles in length and for a part of the year are almost dry.

The largest creek is Big Sniabar which flows into the Missouri river at Wellington. It drains a large area of country south and west of the sheet.

Little Sniabar lies wholly within the sheet, as well as most of Tabo creek. The streams flowing southward near Odessa, reach the Missouri river through Davis creek, Blackwater and Lamine rivers.

FORESTRY.

The greater part of the area was originally, before the occupation of the country by the agriculturalist, covered with

forest trees. The soil was favorable to their growth and the relief was sufficiently strong and the country so much cut by streams that forest fires were held in check. Very little is now left of these original forests. What remains is confined to the rugged parts of the area, to the creek and river bottoms and the steep hillsides. Little of it is large enough for manufacture into lumber, and what is large enough is made up of trees unfit for any excepting the cheapest grades. There has been no effort put forth on the part of the inhabitants to care for the remnants of the woodlands. It has no present value either for fencing, fuel or lumber, and when the land can be cultivated it is removed and the land put to a more profitable use. The forest trees are exclusively deciduous and nearly all are of hard-wood species. Oak and elm are the most important.

The following list includes all the important trees and shrubs occurring within the limits of the area:

Black walnut, *Juglans nigra*, Linn.
White hickory, common shell bark, *Hicoria ovata*, (Mills).
White oak, *Quercus alba*, Linn.
Laurel oak, *Quercus imbricaria*, Michx.
Pin oak, *Quercus palustris*, Du Roi.
Swamp white oak, *Quercus platanoides*, (Lam).
Red oak, *Quercus rubra*, Linn.
Black oak, *Quercus velutina*, (Lam).
American, or white elm, *Ulmus americana*, Linn.
Pawpaw, *Asimina triloba*, (Linn).
Sycamore, *Platanus occidentalis*, Linn.
Wild cherry, *Prunus serotina*, Ehrh.
Red-bud, *Cercis canadensis*, Linn.
White maple, *Acer saccharium*, Linn.

Probably nine-tenths of the timber now standing is made up of black and laurel oaks, elm, cottonwood and linden, in the order of their importance. The black oak is confined principally to the ridges above the loess. The elms flourish in the small valleys in the upland plain, in the loess soils along with laurel oaks and a few linden. Cottonwoods are confined to the creek and river bottoms; and the lindens grow chiefly on the river bluffs.

STRATIGRAPHY.

MAIN LITHOLOGICAL CHARACTERS.

The rocks of the Lexington area consist of shales, sandstones, limestones, coals, clays, conglomerates and soils. They are all sedimentary and are unmetamorphosed. They belong to the clastic and organic divisions of sedimentary rocks. The clastics with one important exception are fine-grained and generally soft. The organic rocks are impure, containing a large percentage of clastic material, but are well lithified.

Shales. The shales are either argillaceous, sandy or bituminous. They are all soft and on exposure soon break down into clay. They are easily eroded and are soon worn down. They are brown, reddish, gray and black in color. The black shales are usually the most resistant to erosion and have the most perfect lamination. Sandy and argillaceous shales constitute a large proportion of the rocks of the area. Bituminous shales form but a small part.

Sandstones. The sandy shales graduate into sandstone and the latter into shales both vertically and horizontally. The sandstones are soft, rather fine-grained and always are reddish in color. They are usually too soft to make a good building material. The sandstones are distributed irregularly through the shales, no one horizon being persistent over the whole area. They are composed of small, well worn quartz grains rather loosely held together by an iron oxide or calcareous cement. They are so soft that their occurence, even among the soft shales, is not marked by any change in topography.

Limestones. The limestones are fine-grained, compact, rather non-crystalline rocks. They usually have a bluish color on fresh fracture, but change to white on exposure. They are highly fossiliferous, the fossils being principally brachiopods and foraminifera. The fossils are imbedded in a matrix of consolidated calcareous mud or clay. Occassionally when closely associated with a coal bed they are highly bituminous though

they are not usually so. They are very irregularly bedded and on exposure break up into irregularly shaped slabs of unequal thickness.

Conglomerates are not important rocks in the district. They are confined to the eastern part, and only occur locally. They are composed of pebbles of the adjacent limestones, shales and sandstones.

Coal. From any other than an economic point of view the coals are unimportant. They are all bituminous, relatively free from pyrite and shale and stand handling well. They contain gypsum in thin plates between the joints but not in sufficient quantity to be injurious for steam purposes.

Clays. The superficial clay of the district is almost altogether a waterlaid glacial deposit, the loess. It is a brownish, faintly stratified loam, made up of the rock flower of the glacial period. It consists in part of pure clay and in part of ground up fragments of undecomposed rock. It contains small pockets of sand scattered through it. The exceeding fertility of the soil of the region is due to this deposit. It contains a large percentage of plant food and is in a condition physically to give this up readily.

GENERAL GEOLOGICAL FEATURES OF THE REGION.

Main Components. The Lexington area lies in western central Missouri. This part of the state is underlain by Paleozoic, Pleistocene and Recent sediments. The Paleozoic sediments belong to the Carboniferous, and to the middle two of its four great series of strata. The Pleistocene deposits are glacial drift and loess; and the Recent are alluvial.

The Carboniferous rocks of the region consist of shales, sandstones, limestones and coals. They all have a very slight dip to the northwest. The rocks, above the base of the series, are all fine-grained sediments and have great persistence along the strike.

The Carboniferous of Missouri consists of three divisions or series: the Mississippian, the Des Moines and the Missourian. Only the latter two are exposed in the Lexington area. The

Des Moines series has been further separated into three subdivisions or terranes. The Missourian has not been subdivided as a whole, though some of its lower beds have received separate names. The formations into which the Des Moines series has been subdivided are the Cherokee shales, the Henrietta limestones and shales and the Pleasanton shales.

The Cherokee shales form the lowest member of the Des Moines series or coal measures. They lie unconformably upon the lower Carboniferous or Mississippian limestones. The formation consists largely of shales and sandstones, with occasional thin bands of limestone and a number of important coal beds. The sandstones predominate near the base of the formation and occasionally pass into conglomerates. In such cases the pebbles are composed of limestone and lower Carboniferous chert. The formation outcrops in a belt of more than 20 miles in width in southeastern Kansas. It enters Missouri in Jasper, Barton, Vernon and Bates counties and trends northeastward. It narrows in this direction until it has a width of only 4 to 5 miles in the northeastern part of Henry county. It abruptly widens again in Johnson, Pettis, Saline and Lafayette counties. After crossing the Missouri river it bends eastward again and continues into Iowa. The thickness of the formation, as exposed in Vernon and Barton counties is nearly 300 feet. In Lafayette and Ray counties drill holes indicate that it is about 400 feet thick.

The Henrietta formation overlies the Cherokee conformably. It is separated from the former on the basis of its lithological character. It consists of shales and limestones with one or two thin but important beds of coal. The limestones constitute less than half the total thickness of the formation, but they are conspicuous on account of their superior resistance and their persistence along the strike. The formation enters the state from Kansas in the western part of Bates county. It trends northeastward in a narrow belt through Henry, Johnson, Lafayette and Ray counties beyond which it has not been well traced. It is probable, however, that it is represented in

Randolph and Macon counties by the limestones and shales lying about 40 feet above the Bevier coal. The thickness of the formation south of the Missouri river is about 75 feet.

The Pleasanton shales overlie the Henrietta beds conformably and outcrop in a belt just west of the latter. The formation consists of shales and sandstones with an occasional very thin, non-persistent calcareous band and one or two beds of coal. All the latter, with one exception, have so far proved to be too thin to work profitably. The whole formation is composed of weak rocks which waste away rapidly into a lowland belt. South of the Missouri river it outcrops in a belt about 25 miles in width, running through Cass, Johnson and Lafayette counties. North of the river the belt widens to more than 50 miles and extends into Iowa. The thickness of the formation in Ray county and southward is about 160 feet.

The Warrensburg sandstone is a formation that overlies the other paleozoic rocks of the region unconformably. It occurs in old erosion valleys which were excavated in the older formations during a temporary uplift. The occurence is therefore in narrow belts striking across the country, bounded on each side by the regular limestones and shales of the Carboniferous. That it is not a conformable member of the series is shown by its juncture with the other rocks in numerous places. The belt to which this name was first applied extends from northern Henry county northward through Johnson and Lafayette into Ray and Carrol, beyond which it has not been traced. Another belt having an east and west trend has been traced from Moberly in the eastern part of Randolph county westward to the western line of the county. It probably unites with the north and south belt in Ray or Carroll county. The age of the beds is presumably Carboniferous. Certain shale beds near Moberly which apparently belong to this formation carry coal plants. No other fossils have been found in it.

The Missourian series has not yet been subdivided in this state. That part of it which lies in Missouri consists of at least two distinct parts, the lower made up of limestones, shales and sandstones aggregating, possibly, a total thickness

of about 400 feet, and an upper member consisting of shales and sandstones with very thin limestones, aggregating nearly 200 feet. The lower division outcrops in a belt about 50 miles wide, the eastern border of which enters the state from Kansas in the northern part of Bates county and extends thence through Cass, Jackson, Lafayette, Ray, Caldwell, Livingston, Grundy and Mercer counties into Iowa. The upper division underlies the northwestern corner of the state beyond the western limits of the lower one.

FORMATIONS REPRESENTED IN THE AREA.

The formations which outcrop in the Lexington area are the Henrietta, the Pleasanton, the lower part of the Missourian and the Warrensburg sandstone, of the Paleozoic, the loess and glacial drift of the Pleistocene, and the Recent alluvium. The relations of these formations to each other are expressed in the following table of formations:

SYSTEM.	SERIES.	FORMATIONS.
Recent.		Alluvium.
Pleistocene.		Loess. Drift.
Carboniferous.	?	Warrensburg sandstone.
	Missourian.	Bethany limestone.
	Des Moines.	Pleasanton shales. Henrietta limestones and shales.

CARBONIFEROUS BEDS.

The Cherokee shales were probably reached in a number of drill holes in the southern part of the district, though the records are not reliable enough of give an idea of the constitution of the formation.

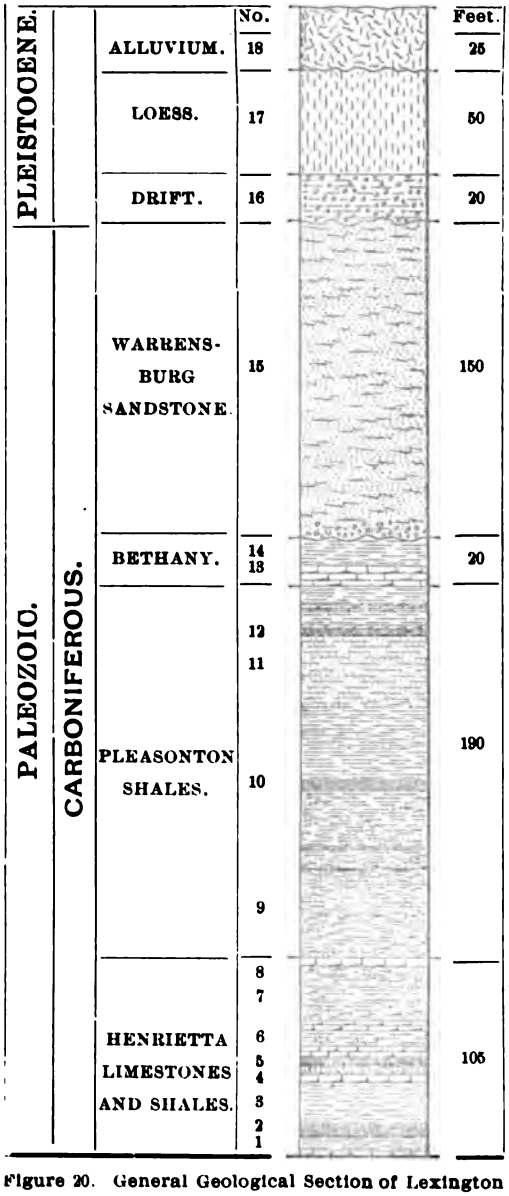


Figure 20. General Geological Section of Lexington Area.

Henrietta Formation. The rocks of this formation outcrop in the bluffs of all the larger creeks and constitute a considerable portion of the surface formations along the eastern side of the area. Its outcrop is important on account of the occurrence in it of the Lexington coal bed, the only one within the area which is above the level of the river and which is thick enough to mine. The strata of which the formation is composed are persistent in character and thickness over the northern part of the sheet, excepting where eroded, but toward the southern part there is a slight change in the character of some of the beds. The change is not great enough however to cause any doubt in correlation, where the facts are clearly given. The formation is made up

of limestones, shales, coals, clays and occasional sandy layers. Its thickness is about 90 feet. The following sections will show its character in different parts of the district. Section I is taken from an exposure in the Missouri river bluffs about 3 miles northeast of Lexington.

I. Section northeast of Lexington.

		Feet.
8.	Limestone	5
7.	Shale	½
6.	Coal (Lexington bed)	1¾
5.	Clay	4
4.	Limestone	3½
3.	Shale	18
2.	Limestone	1⅓
1.	Shale	4

At Bridge 17, a short distance to the west, the rocks beneath this section are exposed as follows:

II. Section at Bridge 17.

		Feet.
6.	Limestone (No. 2, section I)	1⅓
5.	Shale	4
4.	Coal	¼
3.	Clay, blue	6
2.	Limestone	8
1.	Shale, drab	1

Number 2 of this section is probably the lowest member of the formation. The upper members of the formation, those above the Lexington coal bed are exposed in the bluff at Lexington and occur as follows:

III. Section at Lexington.

		Feet.
6.	Limestone, contains abundant chætetes, fusulina and small crinoid stems (top member of formation)	5
5.	Sandstone, and sandy shale	25
4.	Limestone	5
3.	Limestone, argillaceous, thin bedded with shale partings, highly fossiliferous	2½
2.	Limestone, more thickly bedded than No. 3, but still shaly; contains great numbers of *Productus costatus*	2½
1.	Limestone, caprock of Lexington coal bed (No. 8 of section I)	5

The upper part of the formation in the southeastern part of the sheet is displayed in the Strasburg shaft at Mayview:

IV. Section at Strasburg Coal Shaft.

		Feet.
6.	Limestone	11
5.	Shale	16
4.	Limestone	9
3.	Shale, black, fissile	1½
2.	Coal	1½
1.	Clay	8

The upper part is not well exposed in the vicinity of Odessa and the drill-hole records are not reliable for details. The lower part of the formation is exposed on Owl creek about 3 miles northwest of the town. It is as follows:

IX. Section northwest of Odessa.

		Feet.
6.	Limestone (bottom rock, Lexington coal bed)	4½
5.	Shale	17
4.	Limestone	¾
3.	Shale, black, fissile	4
2.	Coal	½
1.	Clay (exposed)	1

Pleasanton Shales. These are the surface rocks over the greater part of the area. They underlie all the central and western part excepting narrow belts along the large creeks and the summits of the high hills north of Odessa. The rocks are shales and sandstones the former being the most abundant. There is in the southern part of the sheet, a thin band of limestone in this formation, but it is not found in the Missouri river bluffs, or north of the river. The shales and sandstones graduate into each other horizontally and vertically. The shales are generally sandy, though some are argillaceous. They are soft and easily eroded. The sandstones are also soft. The cementing material is lime or iron oxide. The average thickness of the formation is about 150 feet. No single exposure shows a persistent relation of shale and sandstone. The formation, as exposed on the Columbus road about 8 miles south of Lexington, is as follows:

VI. Section on Columbus road south of Lexington.

		Feet.
5.	Sandstone, soft, reddish brown	50
4.	Shales	70
3.	Sandstone	20
2.	Shales	20
1.	Limestone (top bed of Henrietta)	3

Three miles west of this locality the formation is exposed in the bluff south of Little Sniabar creek. It is as follows:

VII. Section on Little Sniabar Creek.

		Feet.
3.	Shale, red and drab	20
2.	Shale, sandy with sandstone	60
1.	Shale, argillaceous and sandy	75

The same formation in the vicinity, according to fragmentary evidence, consists of about 90 feet of sandy shale and sandstone at top, then one foot of limestone, and 60 feet of argillaceous shales. A 6-inch coal bed similar to the one occurring at the top of the formation in many places in western Missouri, was noticed in the hill at Greenton. Elsewhere it is absent or covered.

Bethany Limestone. The area underlain by rocks of this formation in the Lexington area is very small. They cap the ridges running northward from Odessa and the other small outliers near them. The formation is barely represented. Further westward it becomes a very important one and underlies a large area of northwestern Missouri. It consists of limestones and shales as represented within the limits of the district. The total thickness represented is about 40 feet. The limestones are exposed on every outcrop, but their details are not well shown. The shales are rarely exposed. A section of the formation outcropping in the hill at Greenton is as follows:

VIII. Section at Greenton.

		Feet.
6.	Concealed (soil)	12
5.	Limestone	10
4.	Shale	10
3.	Limestone	3
2.	Shale	6
1.	Limestone	2

PLEISTOCENE DEPOSITS.

The Bowldery Drift is confined to the extreme northern part of the sheet and occurs as a very thin deposit beneath the lower or water-laid drift. It is a yellowish clay with a few bowlders, some of them local and a few of them of northern

crystalline rocks. The only place at which the deposit has been seen is on the slope of the bluffs 4 miles northeast of Lexington.

Loess, according to Todd, covers nearly the whole of the area. It occurs over all the area below the contour of 900 feet. On the top of the high ridges north of Odessa the superficial deposits are residual clay. The thickness of the loess varies from a few to 50 feet, or even more in some cases on the river bluffs. It consists of a brownish loam having a tendency to a columnar structure on exposure. It contains small pockets of sand irregularly distributed through it and usually lies on a layer of the same material. The stratification is faint, as should be expected in a materal of so uniform texture.

Alluvium occurs along the river and all the large creeks. On the latter it is made up to a great extent of re-arranged loess, with clay from the shales and other country rock. It does not usually contain a large percentage of sand. Gravel beds do not occur at all. The streams flow in mud-lined channels whenever they are down to grade. The alluvium of the Missouri river floodplain is much more sandy than that of the small creeks. It is very friable and readily yields to the current whenever the latter is directed to one side of the channel.

GEOLOGICAL SECTIONS ALONG THE MISSOURI RIVER.

Commencing where the bluffs cross the eastern side of the area and going westward, the first 3 miles shows only sandy beds extending from top to bottom of the bluffs. They are massive and shaly, are all micaceous and of a brownish red color. They are described under the heading "Warrensburg sandstone."

The first exposure of the regular rocks of the coal measures met with is 4 miles east of Lexington, in the small branch in the southeast quarter of section 30 (Tp. 51 N., R. XXVI, W.). The rocks exposed are about as follows:

IX. Section 4 miles east of Lexington.

		Feet.
3.	Limestone, "bottom rock" of Lexington coal bed	3
2.	Shale, argillaceous	15
1.	Limestone, a single massive layer (about 700 feet A. T.)	1

No other exposures occur for some distance excepting the outcrops of a single bed of limestone near the head of the next ravine east of this. North and west of the locality in section 1 (Tp. 51 N., R. XXVII W.), for more than a mile, the bluffs are covered with a heavy coating of loess which conceals the underlying rocks.

In the northeast quarter of section 24, the following section occurs at the mouth of an abandoned coal mine:

X. Exposure in Section 24.

			Feet.
11.	Limestone, (about 725 feet A. T.)		5
10.	Shale, black fissile		½
9.	Coal.		⅛
8.	Shale } Lexington bed.		¼
7.	Coal.		1¼
6.	Clay		4
5.	Limestone (bottom rock Lexington coal bed)		3½
4.	Shale, argillaceous, blue, to reddish toward base		18
3.	Limestone, a single bed		1
2.	Shale, bituminous		4
1.	Clay (exposed)		2

At bridge No. 17, on the Jefferson City and Boonville branch of the Missouri Pacific railroad, a short distance west of the Kerdoff mine, the following rocks were exposed:

XI. Section west of Kerdoff Mine.

		Feet.
6.	Limestone (No. 3 of section X.)	1½
5.	Shale, dark	4
4.	Coal	¼
3.	Clay, blue	6
2.	Limestone	3
1.	Shale, drab (about 685 feet A. T.)	1

These are the lowest rocks examined in any outcrop within the area of the sheet. Westward they dip gradually beneath the water in the river. The strata rise in a few places near Lexington enough for these beds to become visible again, but

their place is covered by a heavy bed of loess. At bridge No. 16, a short distance west of No. 17 the bottom rock of the Lexington coal bed is about 7 feet above the railroad, and No. 2 of section XI is at the edge of the water in the river.

At bridge No. 14, about 1,500 feet east of the Riverton mines, the bottom rock is 6 feet above the railroad track and the interval between that and No. 6, of section XI is 18 feet. The latter here lies 4 feet above the water in the river. In the railroad cut between this and Riverton the following rocks occur:

XII. Section East of Riverton.

		Feet.
6.	Limestone (cap-rock of Lexington coal bed)	5
5.	Shale, black, fissile	⅔
4.	Coal (Lexington bed)	2
3.	Clay	3
2.	Limestone	4
1.	Shale (to railroad, about 700 feet A. T.)	7

The McDowell well is located 400 feet south of the railroad and 200 east of Wilmot branch. The top of the well is 30 feet above the track. It is 80 feet deep, with 30 feet of loess, 40 feet of reddish shale and 10 feet of rock which is called sandstone. The coal and most of the limestones an replaced here by the loess, and the shale seems to take the place of the lowest limestone described in the foregoing sections. At Riverton the bottom rock of the Lexington coal bed is 10 feet above the railroad track. It rises slightly westward for a short distance and then begins to dip, and at the railroad bridge near the line between sections 22 and 27 the coal is 12 feet below the railroad level. The rocks exposed here are about as follows:

XIII. Section West of Riverton.

		Feet.
5.	Limestone, massive	3
4.	Shale, with thin beds of shaly limestone	7
3.	Limestone, cap-rock	6
2.	Shale, black, fissile	⅔
1.	Coal (Lexington bed) about 687 feet A. T.	1½

Just below the old warehouse, at the foot of Pine street, in Lexington, the rocks exposed in the bluff are:

XIV. Section at foot of Pine Street, Lexington.

		Feet.
10.	Concealed from top of bluff	100
9.	Limestone, containing abundant fossils (Monticulipora, fusulina and small crinoid stems)	5
8.	Sandstone, not persistent, shaly, occurring only in thin beds in shale and passing downward into shale	25
7.	Limestone	5
6.	Limestone, argillaceous, thin-bedded, with shale partings, highly fossiliferous, (chonetes bed)	5
5.	Limestone, more thickly bedded, but containing shale layers, highly fossiliferous (Productus bed)	2½
4.	Limestone (cap-rock)	5
3.	Shale, black, fissile	⅗
2.	Coal	1½
1.	Clay (about 700 feet A. T.)	4

In the city of Lexington between the water tower and the Female College building, a shaft was sunk in 1883. The work was done by Peter Ward, of the Lexington Coal Company, who furnished the following record:

XV. Record of Lexington Shaft.

		Feet.
15.	Clay (about 860 feet A. T.)	40
14.	Sand	3
13.	Shale	40
12.	Limestone	4
11.	Shale	4
10	Shale, dark colored, "black jack"	4
9.	Sandstone	9
8.	Shale, dark, "black jack"	2
7.	Shale	7
6.	Limestone, white	5
5.	Shale	4
4.	Shale, dark "black jack"	3
3.	Limestone, blue	5
2.	Shale, black, fissile	⅛
1.	Coal (Lexington bed)	2

Recently a shaft has been sunk by the Southwestern Coal Co., about 1000 feet east of the railroad station at Lexington. The following record was furnished by Edward Aull of Lexington, the superintendant:

XVI. Section at Southwestern Shaft.

		Feet.
10.	Clay, hard (about 800 feet A. T.)	40
9.	Gravel and clay	5
8.	Sand, yellow	12
7.	Mixture of limestone bowlders, pieces of coal, shale and clay, with clay	28

		Feet.
6	Limestone, white	6
5.	Shale	$^{2}/_{3}$
4.	Limestone, caprock	6
3.	Shale, black, fissile	$^{2}/_{3}$
2.	Coal	2
1.	Clay	$3^{1}/_{2}$

On Graham branch, above the railroad bridge near Myrick station, the rocks exposed in the bank are:

XVII. Section on Graham Branch, near Myrick.

		Feet.
8.	Limestone bottom rock of Lexington coal bed about 690 feet A. T.	$3^{1}/_{2}$
7.	Shale, at top argillaceous to sandy, yellowish, becoming blue and finally very dark near the base	16
6.	Limestone, single bed	$1^{1}/_{2}$
5.	Shale, dark, graduating into the next below	1
4.	Shale, black, fissile	1
3.	Shale, black, pyritiferous	2
2.	Coal	$^{1}/_{2}$
1.	Clay (exposed)	$2^{1}/_{2}$

About 400 feet below Myrick station, in a small ravine, the rocks show a slight change in the same horizon between this point and the old warehouse at foot of Pine street in Lexington, as the following section indicates:

XVIII. Section East of Myrick.

		Feet.
5.	Limestone, massive (about 740 feet A. T.)	1
4.	Shale, argillaceous, drab	$3^{1}/_{2}$
3.	Shale, dark blue	$3^{1}/_{2}$
2.	Limestone, compact (cap-rock of Lexington coal bed)	$1^{1}/_{2}$
1.	Shale, black, fissile	6

The following section is reported by Norwood on the bluff near the ferry landing at Lexington:

XIX. Section at ferry landing, Lexington.

		Feet.
28.	Loess	52
27.	Shale, bituminous	15
26.	Shale, bituminous, with thin coal streak	$^{1}/_{8}$
25.	Shale, sandy	7
24.	Sandstone, shaly, buff	6
23.	Shale, dark; some parts hard and calcareous	16
22.	Limestone, blue, concretionary, weathers brown	$^{1}/_{4}$
21.	Clay, blue, streaked with red	$7^{1}/_{2}$
20.	Coal	$^{1}/_{4}$
19.	Shale, dark	$^{1}/_{4}$
18.	Fire-clay	$^{1}/_{2}$

		Feet.
17.	Slope	4
16.	Limestone, irregularly bedded, drab, abounds in Chætetes and Fusulina	5
15.	Shale, drab and dark	5
14.	Sandstone, hard, brown, single thick bed, also gray or drab	3
13.	Shale, buff and olive	8
12	Limestone, drab, thick-bedded; shaly on top; good for building, contains *Chætetes milleporaceus*, Fusulina, Athyris, etc	5
11.	Shale, drab and dark blue, with thin beds and nodules of limestone	4
10.	Limestone, dull blue, irregularly bedded	4
9.	Shale, with pyritiferous concretions	¼
8.	Shale, bituminous	⅔
7.	Coal, 1½ inches	
6.	Shale, very hard, pyritiferous	4
5.	Coal, working bed (Lexington bed)	1¾
4.	Clay	2
3.	Slope	3
2.	Limestone, thick-bedded, gray	3
1.	Slope, to level of the Missouri river	28

The bluffs southwest of this and reaching to the western limit of the area have a heavy covering of loess. Exposures in the narrow ravines cutting them are abundant, but as a general rule, only a few feet are exposed at a place. The great number of coal mines serve to locate the coal bed and give evidence that there is no great break in the stratigraphical continuity. In the northeast quarter of section 5 (Tp. 41 N., R. XXVII W.), is a shaft known as the McGrew "Machine mine." The following is the record:

XX. Record at the McGrew Mine.

		Feet.
13.	Soil (about 770 feet A. T.)	1
12.	Sandstone, soft, coarse	2
11.	Shale, blue	11
10.	Limestone, white	7
9.	Shale, blue, last 2 feet are hard and shelly	7
8.	Limestone, gray, compact	7
7.	Limestone, nodular	½
6.	Shale, black, fissile	1
5.	Pyrite band "black jack"	½
4.	Coal (Lexington bed)	1½
3.	"Mining clay"	1-6
2.	"Sulphur" (pyrite band)	½
1.	Clay	4

A well sunk at the edge of the river bottom 1,500 feet above Myrick, after passing through 2 feet of soil went 18 feet

in "drab soapstone with bowlders." The top of the well is 30 feet below the Lexington coal bed. The "soapstone with bowlders" may be drift clay. The air-shaft of the Graddy mine passed through 35 feet of red, blue, and yellow shale above the caprock as well as the 12 feet of fossiliferous rocks overlying it. Above the Graddy mine the rocks dip slightly westward. At the McGrew drift No. 2 the Lexington coal bed is but a few feet above the river floodplain, while still further up the railroad at the abandoned McGrew shaft the coal bed was about 20 feet below the floodplain. It soon rises, however, and about one mile east of Wellington the coal is 15 feet above the railroad. It soon dips westward again, and at Wellington it lies about 40 feet below the railroad. It does not again come to the surface west of this. No record of the shaft at Wellington is available, but the following record of the air-shaft of the Seawell and Hackett (Hartman) mine located 2 miles west of Wellington is here given for purposes of comparison.

XXI. Section at Seawell and Hackett Mine.

		Feet.
14.	Soil and red clay (about 725 feet A. T.)	4
13.	Drift, sandy	8
12.	Sandstone	2
11.	Clay, red	4
10.	Limestone, blue	4
9.	Shale, colored	20
8.	Limestone, white (cap-rock)	7
7.	Shale, white and blue	20
6.	Limestone	7
5.	Shale, black, fissile	1
4.	"Black jack" and "sulphur"	½
3.	Coal	1½
2.	Clay	5
1.	Limestone	8½

The most noteworthy feature shown in this record is the thickening of the shaly calcareous bed overlying the caprock. Here it (No. 9) is 20 feet thick, while at Lexington it is only 6 to 7 feet. On the opposite side of the river, from Wellington, a small part of the Ray county bluffs come into the Lexington area. They are covered with loess which hides all other exposures. The coal has been worked at places sufficiently numerous to show the general relations of the strata. Where

the bluffs enter the area in section 8 (Tp. 51 N., R. XXVII W.) the coal bed lies a few feet above the contour line of 700 feet and continues at about this height through the section. Its outcrop was not seen west of this, but in the southern part of section 13 (Tp. 51 N., R. XXVIII W.) the coal was reached several years ago from the foot of the bluff by a shaft 12 feet deep. Broadhead refers to an outcrop of the coal west of this.

Within a very short distance from the western edge of the sheet, where the line of bluffs cross it, the coal is reached in a shaft at a depth of 20 feet below the level of the river flood-plain. To the west a short distance, the coal rises to the level of the railroad and a little above it as recorded by Broadhead. It then dips westward and does not again appear at the surface. The report on the Richmond sheet gives the record of a number of shafts in the vicinity of Richmond only a short distance north of the river.

SECTIONS ALONG THE CHICAGO, ALTON AND ST. LOUIS RAILROAD.

Along Rocky branch, near the point at which the Chicago, Alton and St. Louis railroad enters the area from the east, the limestone associated with the Lexington coal bed is frequently exposed. The vertical extent of the outcrops is never great, but is enough to show where the rocks belong. The Lexington coal is extensively mined a short distance up the branch by both shafts and drifts. South of this, along Tabo creek, exposures even of the hard limestones are very rare. At the Fishback place (Tp. 49 N., R XXVI W., Sec. 29, Ne. qr.) the coal has been mined by drifting. The outcrop at the mouth of the drift shows 6 feet of limestone caprock, with about 2 feet of black, fissile shale beneath it, and above the coal. Half a mile northwest, the coal bed is reached in a shaft 27 feet deep. The Strasburg shaft is about a mile east of Mayview. The following approximate record is reported:

XXII. Record of Strasburg Shaft.

		Feet.
13.	Soil (about 840 feet A. T.)	5
12.	Clay	10
11.	Clay, white	9

		Feet.
10.	Limestone, gray	⅔
9.	Shale	20
8.	Limestone, yellow	2
7.	Limestone, hard, yellowish	9
6.	Shale	2
5.	Shale, yellowish, becoming bluish toward base	15
4.	Limestone, hard, bluish	9
3.	Shale, black, fissile	1¼
2.	Coal	1½
1.	Clay	3

A shaft sunk about two years ago by the Matthews Coal Co., is located 1,200 feet west of the railway station at Mayview.

On the Powell property, there is a well 136 feet deep, which is in sandstone with no coal. On the McCulloch place, in section 27, a well 124 feet deep passes through no coal. A well on the Jennings land in the same section, 156 feet deep, passed through coal near the bottom, but the thickness was not recorded.

Westward from Mayview, along the railroad, sandy shales are exposed everywhere in the ravines. On the largest stream flowing southward some limestone beds are exposed near the southern line of the area. Farther west, about two miles east of Odessa are several dug wells, all excepting one of which are in shale. In one of them a limestone was reached at a depth of 45 feet. A limestone crops out, at about the same elevation as in the well, in the creek in the southeast quarter of section 23 (Tp. 49 N., R. XXVII W.). In the neighborhood of Odessa a number of drill-holes have been put down. The records of some of them that were obtained are here recorded. There is apparently some conflict among them. They were most of them reported from the memory of the owners or drillers, and must be taken with some allowance. On the Ewing place (Tp. 49 N., R. XXVII W., Sec. 27, Ne. qr.), a well was dug to the depth of 50 feet, in the bottom of which a drill-hole was sunk 26 feet farther. The record is:

XXII. Record of the Ewing Well.

		Feet.
8.	Soil (about 880 feet A. T.)	4
7.	Clay	15
6.	Interval	23
5.	Limestone, hard	1
4.	Shale, sandy	10
3.	Limestone	1
2.	Interval	25
1.	Sandstone, bottom of well	1

A number of dug wells in Odessa pass through about 25 feet of soil and sandy shale to a bed of limestone, 18 inches thick, underlain by clay and sandstone. The limestone here recorded is found in the ravines in the vicinity. In the Hatch well (Tp. 49 N., R. XXVII W., Sec. 32, Sw. qr.), the upper 50 feet were dug, and the rest drilled:

XXIII. Record of the Hatch Well.

		Feet
22.	Soil and clay (about 920 feet A. T.)	14
21.	Sandstone, brownish red, soft	29
20.	Sandstone, grayish, hard	19
19.	Shale	9
18.	Shale, black	4
17.	Coal	1¾
16.	Clay	⅝
15.	Shale, very hard, compact	10
14.	Shale	18
13.	Sandstone, hard, gray, sharp	5
12.	Shale	1
11.	Limestone, hard, light gray color	7
10.	"Pebbly material" hard, black	1½
9.	Shale, black, fissile	2
8.	Coal (Lexington bed)	1½
7.	Shale	8
6.	Limestone, hard, grayish	10½
5.	Limestone, shelly	4
4.	Sandstone	6
3.	Shale	21
2.	Shale, black	2
1.	Coal	1¼

From this level to the bottom, about 80 feet of limestone and sandstone in alternating strata are reported. It is quite probable that much of the limestone reported in this well is really sandstone. The record reported of the Kirkpatrick well (Tp. 49 N., R. XXVIII W., Sec. 36) is as follows:

XXIV. Record of the Kirkpatrick Well.

		Feet.
15.	Soil and clay	18
14.	Shale	25
13.	Sandstone	25
12.	Limestone (?)	1½
11.	Shale, black	½
10.	Coal	½
9.	Shale	....
8.	Limestone—hard, yellowish white	9
7.	Shale, black, fissile	6
6.	Coal (Lexington bed)	2
5.	Clay, blue	½
4.	Shale, with thin calcareous beds	26
3.	Limestone	2
2.	Shale, sulphur and coal mixed	6
1.	Clay and shale	4

Of the Lee well (Tp. 48 N., R. XXVIII W., Sec. 1, Nw. qr.) no record was available, but a bed of coal 18 inches in thickness was encountered at a depth of 266 feet, and another of 23 inches at a depth of 301 feet. The top of the well is about 830 feet A. T. The record of the Wayman well (Sec. 3, Ne. qr.) is as follows:

XXV. Record of the Wayman Well.

		Feet.
26.	Soil and clay (about 900 feet A. T.)	18
25.	Sandstone	12
24.	Shale, yellowish	13
23.	Rock, hard, gray, flinty	4
22.	Coal	⅔
21.	Shale, soft, black	⅜
20.	Shale, blue	⅘
19.	Rock, hard, gray (limestone)	2
18.	Shale, blue	15
17.	Shale, black	¼
16.	Coal	1
15.	Clay	2½
14.	"Gravel"	8
13.	Shale, blue	2½
12.	Soft, dark material	2
11.	Sandstone, yellowish	8½
10.	Shale, blue	8⅓
9.	Rock, shelly, gray (limestone)	1
8.	Shale, black	5½
7.	Shale, black	½
6.	Coal	1¼
5.	Clay	1
4.	Rock, gray, hard	⅘
3.	Shale, blue-black	5-6
2.	Shale, black, fissile	⅘
1.	Coal	2¼

The Lexington coal bed has been mined in the southeast quarter of section 33, where it is reached by a shaft 14 feet deep. The coal is overlain by 16 inches of black shale, and that in turn by 8 feet of limestone. It has also been worked in the northeast quarter of section 27. The black shale here is 20 inches thick, and the exposed part of the cap-rock is about 6 feet. The coal is 16 inches thick. In the bank of Owl creek, west of this, the following rocks are seen:

XXVI. Section on Owl Creek.

		Feet.
6.	Limestone (bottom rock of Lexington coal bed)	1
5.	Shale, becoming dark below	17
4.	Limestone	⅔
3.	Shale, black, fissile	4
2.	Coal	½
1.	Clay	1

At the northeastern corner of this section sandstone is to exposed, several feet thick. Along the road a short distance to the north are many loose limestone blocks, but the ledge from which they were derived is not visible.

SECTIONS ON BIG AND LITTLE SNIABAR CREEKS.

The hills north of Odessa are everywhere capped with heavy beds of limestone, which gives marked character to their slopes. They rise more or less gradually from the lower plain to near their top, where they become very steep and often quite rugged. The following is the section coming down the hill at Greenton:

XXVII. Section at Greenton.

		Feet.
9.	Concealed (about 1,000 feet A. T.)	15
8.	Limestone	12
7.	Shale, and concealed	12
6.	Limestone	3
5.	Concealed	6
4.	Limestone	2
3.	Concealed	8
2.	Clay, calcareous	2½
1.	Shale and sandstone	70

West of Greenton, sandstone and shales are abundantly exposed along the heads of the small streams. Lower down

on the streams the Lexington coal and its associated limestones are exposed, and the coal has been mined at a number of places. The Armstrong shaft (Tp. 49 N., R. XXVIII W., Sec. 10, Sw. qr.) is 30 feet deep. The black shale is 18 inches thick and the coal 16. The underclay is only 8 inches in thickness. Near the southwestern corner of section 3 a limestone is exposed which is probably the cap-rock of the Lexington coal. The strata dip slightly northward from this point and no outcrops are seen for some distance. Near the bridge in the northern part of section 34 (Tp. 50 N., R. XXVIII W.) some beds of limestone are exposed which are without much doubt associated with the Lexington coal bed, but their exact position is not yet determined. The following section, by Broadhead, includes the rocks outcropping from the top of Graddy knob northward to the bridge just referred to:

XXVIII. Section at the Graddy Knob.

		Feet.
14.	Limestone, light drab, irregularly bedded, top shelly, contains Fusulina and crinoid stems	2½
13.	Limestone, bluish drab, tolerably coarse-grained, somewhat ferruginous, weathers brown, calcite seams and specks disseminated, Athyris and crinoid stems abundant	2
12.	Slope	165
11.	Sandstone, soft, brown	2
10.	Slope	15
9.	Limestone, gray, coarse-grained, silicious, abounding in crinoid stems	⅔
8.	Shale, sandy	2
7.	Slope	72
6.	Limestone, upper part bluish, lower part light drab, contains Athyris, Productus, Chætetes, etc.	3½
5.	Slope	5
4.	Shale, and nodules of limestone, abounding in Chonetes with a few Producti	5
3.	Clay	2
2.	Shale, dark, passing into thin layers of dull, blue limestone abounding in Productus, Athyris and Chonetes	2
1.	Limestone, dull blue, irregularly bedded, argillo pyritiferous, containing crinoid stems, Productus, Hemipronites and Spirifer	2

The Lexington coal and its associated rocks are seen in the bed of the creek in the southwest quarter of section 23 of the same township. Around the headwaters of Little Sniabar creek the shales and sandstones of the Greenton section are every-

where exposed, with the limestones of the same section exposed near the tops of the hills, but the details of the sections are somewhat obscure. The sandstones and shales between these overlying limestones and the next thick underlying bed of limestone are about 140 feet thick and include one thin bed of limestone 10 inches thick, with probably some concretionary beds. This thin bed within the shale was seen in the northeast quarter of section 16 (Tp. 49 N., R. XXVII W.) and is supposed to be the same bed as the one in the northeast quarter of section 20 of the same township.

In the creek, half a mile west of the first mentioned locality, a bed of limestone is exposed. About three-fourths of a mile north of this, at the ford, the same rock lies in the bed of the creek. The section here is as follows:

XXIX. Section at Ford on Little Sniabar Creek.

		Feet.
6.	Limestone, (about 780 feet A. T.)	⅘
5.	Shale, drab	1¼
4.	Limestone	⅔
3.	Shale	2
2.	Limestone	1½
1.	Shale, in bed of creek	1

The same limestone is exposed in the branch near the middle of the east line of section 6 of this township. It is underlain only a short distance below by several feet of sandstone. In the southeastern corner of section 4, and 3 miles northwest of Mayview, is an outlying remnant of the high plateau that once extended over the area. The rocks exposed in the road on its northern side are about as follows:

XXX. Section 3 miles northwest of Mayview.

		Feet.
7.	Limestone (about 965 feet A. T.)	2
6.	Sandstone, soft	30
5.	Interval (shale)	70
4.	Sandstone	20
3.	Shale	20
2.	Limestone	3
1.	Shale, blue (exposed)	3

The Lexington coal bed is exposed in the bank of Little Sniabar creek near the northern line of section 32 (Tp. 50 N.,

R. XXVII W.). A little further down the creek the coal is mined in several places. The rocks exposed in the road from the top of the hill in section 31 to the bed of the creek near the center of section 30, about 3 miles southeast of Wellington, are as follows:

XXXI. Section 3 miles southeast of Wellington.

		Feet.
15.	Limestones, and concealed interval, details not readily made out (about 980 feet A. T.)	25
14.	Shale, drab and red	25
13.	Shale, sandy, and sandstone	65
12.	Interval	70
11.	Limestone	8
10.	Shale, with thin calcareous layers, fossiliferous	8
9	Shale, sandy, calcareous, fossiliferous	4
8.	Limestone, cap-rock	7
7.	Shale, black, fissile, clay at top and below	1½
6.	Coal (Lexington bed)	1½
5.	Clay	1¼
4.	Shale, argillaceous, white, red and blue	15
3.	Limestone	3
2.	Limestone	1
1.	Shale, blue (exposed)	3

One and one-half miles from Wellington, in the valley of Little Sniabar creek in the western part of section 24 (Tp. 50 N., R. XXVIII W.), the beds immediately below the Lexington coal are exposed. They are as follows:

XXXII. Section on Little Sniabar, southeast of Wellington.

		Feet.
7.	Limestone, bottom rock (about 725 feet A. T.)	3½
6.	Interval (shale)	12
5.	Limestone	1
4.	Shale, black, fissile	1¼
3.	Shale, black, pyritiferous	2½
2.	Coal	3
1.	Clay and shale (exposed)	6

In the eastern half of this township and the western half of the township to the east, there are no prominent outcrops of Paleozoic rocks. Shales are frequently exposed in the ravines but only a few feet in a place. In several places a coal bed which is correlated with the Lexington coal, has been mined. These scattered coal mines are located on the map.

There are no records of drill holes in the vicinity of these mines. The fact that the Lexington coal bed exists here and with the same association of strata as elsewhere is some indication that the rocks are the same as in neighboring localities.

Over a part of the Lexington area coal has not been found. This is in the area occupied by what has been called the Warrensburg sandstone.

For a description of this sandstone belt as it exists in the Higginsville area, which joins the Lexington sheet on the east, and for its interpretation based upon the evidence gathered in that area and this one, reference is made to the report on that area.* Its extension northward in Ray county is described in the report on the Richmond sheet. Its outlines within the area of the Lexington sheet are shown on the map. No facts that in any way conflict with the interpretation given in the first report referred to above have been found in the area of the Lexington sheet. Its actual juncture with the other Paleozoic rocks has nowhere within this area been met with. All that need be said in this place is that the evidence confirms the opinion that it is of later deposition than the other Paleozoic rocks of the region; that its area is small; that it lies unconformably on these rocks, and that where it is present the others are absent; that it fills a channel of erosion which was made in these Paleozoic rocks after they had been deposited and elevated above sea level; that the elevation making possible this erosion was not insignificant like many of the minor oscillations of the seashore at all times, but that it was widespread and of sufficient duration to allow the development of an extensive drainage system, but all happening within the time represented by the Carboniferous period.

The thickness of this sandstone is not known. It is not probable, however, if the interpretation of it is correct, that it is thick enough to cut out all of the coal measures. It is, therefore, not to be assumed that no coal whatever can be found within this belt.

* Winslow; The Higginsville Sheet. Geological Survey of Missouri, 1892.

GEOLOGICAL STRUCTURE.

The structure of the region is extremely simple. There has been little or no warping, folding or faulting of the strata. In fact, all the departures of the strata from a conceivable plain of deposition can be very readily explained by unequal settling and compression of the rocks.

SOILS.

The soils of the area are residuary, and foreign or transported. The residuary soils are very limited in extent and are not important. They are not so productive as the transported soils, and in addition to that they are unfavorably located. They have been left until very recently without much attention. They support a very good growth of oak timber, and when cleared produce very good crops for a few years, though they are more easily exhausted than the transported soils. They are confined to those parts of the area which lie above the contour line of 940 feet. This confines them to the hillsides and tops of the knobs and ridges described under topography. The most rugged parts of these lands are still covered with timber, but the gentler slopes are being brought under cultivation rapidly.

The transported soils cover most of the area. They may be classed under two divisions: (1) the loess, and (2) the alluvium.

The loess covers all the uplands below the contour line of 920 feet, except in the floodplains of the streams and even the material along the small streams is principally derived from the loess. It is the foundation of the agricultural wealth of the region. It forms a soil that leaves little to be desired. It is a warm, open, porous, well-drained and fertile soil, easily tilled and needing no fertilizers. Enough has been done however to show that the resources of the soil are not inexhaustible. In some places its productive capacity has been impaired by a series of successive annual demands made upon it in growing hemp. The loess is liable to "wash" badly in many

places. It is still unconsolidated and the rolling topography gives considerable advantage to the drainage.

The alluvium is confined to the river and creek bottoms. A strip of greater or less width extends along all the larger creeks. The most extensive body being in the floodplain of the Missouri river. It has not been so important a factor in the prosperity of the region as the loess, although its area is considerable. When the country was first settled much of the bottom land was covered with a heavy growth of timber, which impeded what tendency to drainage there was, and also prevented the evaporation of the surplus water. The low lands were then very unhealthful places in which to live. They remained for many years little more than wild wet wastes inhabited only by a few sickly squatters. Gradually however the land was brought under cultivation, a few small drainage ditches were dug and much of the unhealthful conditions vanished. No systematic attempt has been made toward draining these lands so that large areas yet remain fit for nothing but grazing purposes. The soil is closer and colder than the loess soil yet when drained and well cultivated its yield is abundant. Another thing which has been a factor in hindering the agricultural development of the Missouri river bottom lands is the risk of having the property taken away without warning or compensation. A farm is continually in danger of being washed away by the ever-changing current of the capricious river, leaving a waste of sand and making a channel for itself where only a short time before lay a prosperous farm.

COAL DEPOSITS.

NUMBER AND CHARACTER OF THE COAL BEDS.

Coal has been mined in Lafayette county for many years. The industry was begun nearly half a century ago. For a long time the greater part of the output was consumed by steamboats, which at that time, were the only means of traveling through this country. The mining was confined to a very few places in the vicinity of Lexington where the Lexington coal

bed outcropped above the level of the water in the river and near a regular boat-landing.

The mining was done at first altogether by slaves and was carried on in the most simple way. The conditions were favorably for mining without much expense or any knowledge of mining methods. With the abolition of slavery and the building of railroads through the region a great change took place in the coal mining industry. It became more widely distributed over the region than before; it was developed with more skill on account of the class of men who engaged in it and also because of the necessity of reaching the coal by shafts and thereby providing for ventilation and drainage. The much larger scale on which it was developed made it necessary to develop a particular piece of property in a more systematic way. Coal land became much more valuable than ever before and created the necessity for getting as much of the coal from an acre as possible. The industrial development of the region and the growing importance of Kansas City as a market for coal has been a great factor in the development of the mining industry of Lafayette county.

The coal mined in the area of the Lexington sheet all comes from one bed, the Lexington bed. Below it in the eastern part of the county the Mulky bed is worked, but within the Lexington area the existence of this bed has not been proved. It lies about 50 feet below the Lexington coal in the eastern part of the county. Its existence could easily be proved by drilling at Lexington. Other beds which lie beneath the Mulky bed in the eastern part of the county may exist under the Lexington area though it is not to be inferred that they do merely because they occur in that position elsewhere. In the southern part of the Lexington area several drill-holes have been sunk deep enough to penetrate the Mulky coal, but the records are so unsatisfactory that very little information can be got from them. A thick bed of coal is reported in one drill-hole at a depth of several feet though it is not at all certain that a bed of black shale has not been mistaken in this case for coal.

Above the Lexinging coal there are no workable beds in the area. Between it and the highest rocks of the district there is an interval of about 250 feet of coal measures, yet there is not a coal bed known within it.

GEOGRAPHICAL DISTRIBUTION OF THE COAL.

The Lexington coal bed originally underlay the whole area covered by the Lexington sheet. Its present somewhat more restricted extent is due to erosion subsequent to its deposition. The area underlain by it has been decreased by two periods of erosion. The first was the period of erosion, probably in Carboniferous times, which excavated the valley in which the Warrensburg sandstone was deposited later. During this period the coal bed was cut out from the belt occupied by the Warrensburg sandstone. The other period of erosion is the present. By it the coal has been cut out from the floodplain belt of the Missouri river and little notches have been cut into it by the larger creeks which flow into the Missouri river. The only streams which have cut beneath the coal in the area are the two Sniabar creeks and Tabo creek. The area cut out by them is, however, very small. The outcrop of the Lexington coal bed is shown on the accompanying geological and topographic map.

The mining industry of the Lexington sheet is still most extensively developed along the Missouri river. There are two well equipped mines on the Chicago, Alton and St. Louis railroad, and several smaller ones scattered over the area.

MINES ALONG THE MISSOURI RIVER.

The most easterly place along the Missouri river bluffs in the Lexington area where coal is now mined is at the Kerdoff mine near the center of section 24 (Tp. 51 N., R. XXVII W.) A section of the coal bed is as follows:

XXXIII. Details of Coal Bed at Kerdoff Mine.

		Inches.
8.	"Top slate"	2
7.	Shale, black	4
6.	Coal (top bench) very bony	8

		Inches.
5.	Black jack, with very thin coal	3
4.	Coal (bottom bench)	19
3.	Clay	12
2.	"Sulphur"	6
1.	Clay (exposed)	86

The black shale contains clay concretions, and the coal, pyrite and gypsum, the latter in vertical seams. There are also rolls or slips. A mine was opened several years ago a few hundred feet to the east in the bluff, but it is now abandoned. A section of the coal bed at the mouth of the old drift is nearly the same as given above. The top coal is 4 inches and the bottom coal is about 17 inches thick.

The Riverton mines are located in the bluffs near the mouth of the Wilmot branch. The McDowell mine, the only one on the east side of the branch, was abandoned several years ago on account of a poor roof. No measurement of the coal bed at Riverton mine No. 2 was made, but at Riverton No. 1 the following is the average of 10 measurements made in different parts of the mine:

	Inches.
Limestone	90
Shale, black, fissile	6
Coal	4
Clay, shaly, black	2
Coal	20
Clay	½
Coal	2
Clay, pyritiferious	86
Limestone	12

Figure 21. Section of Coal Bed at Riverside mine.

A short distance up stream from the Riverside mine No. 1 is the McDowell shaft, operated by the Lexington Coal Mining Company. The top of the shaft is 25 feet above the railroad, and the coal is reached at a depth of 42 feet. The details of the coal bed are as follows:

XXXV. *Details of Coal Bed in McDowell Shaft.*

		Inches.
8.	Shale, "roof slate"	2
7.	Shale, black, fissile	4
6.	Coal (top bench)	4
5.	Shale, "black jack"	4
4.	Coal (bottom bench)	20
3.	Clay	2
2.	"Sulphur"	6
1.	Clay	30

The next opening now operated is the Clark drift, in the southeast corner of the northeast quarter of section 28. The Walton drift is just across the line on the next 40-acre tract to the south, in which are reported 18 inches of coal, without the clay parting overlain by 5 to 9 inches of black shale. Another drift that is in operation is located 200 feet below the old warehouse at the foot of Pine street, Lexington. At the last three drifts mentioned the coal seam is on a level with the railroad. A small mine, the Mulligan, is opened from the hillside above the pumping station of the waterworks at Lexington. The coal bed lies here about 35 feet above the railroad. At the Rosewell shaft, recently sunk in the northeast quarter of section 29, the depth and details of the coal bed were not obtained. It is operated to supply a local demand for fuel only.

In a new shaft sunk by the Southwestern Coal Company in the southeast quarter of section 34 (Tp. 51 N., R. 27 W.), the coal is 18 to 20 inches thick, overlain by about 8 inches of black shale. The capacity of the mine at present is six cars a day. The output is shipped to Kansas City and intervening local points. Only a short distance east of this shaft, in section 35, on the railroad, are two abandoned shafts of the Lexington Coal Mining Company. They have been deserted for several years, but the details of the coal bed, as copied from the books of the company, showed the average of the seven measurements made in the two shafts to be as follows:

XXXVI. Coal Bed in old Lexington Shafts.

		Inches.
7.	Shale, "roof slate"	2
6.	Slate, black	6
5.	Shale, band slate	3
4.	Coal (top bench)	3
3.	Black-jack	3
2	Coal (bottom bench)	20
1.	Clay	32

The Seawell mine, operated by the Lexington Coal Mining Company, is located in the southeast quarter of section 32. There is no "slate band" reported here, and the coal is 21 inches in thickness, this being an average from measurements, made in four entries. Two shafts, operated by horse-power,

are located in the northern part of section 4 on Graham branch. The output is consumed in Lexington. They are both shallow shafts, though the exact depths are not known.

The Hackett and the Taylor mines, formerly owned and operated by the Lexington Coal Mining Company, are located on the river bluff in section 5. They were abandoned several years ago. The McGraw shaft was opened near the center of the same section. It is equipped with a steam hoist and is connected with the Missouri Pacific railroad by a spur. It has not been operated for several years, though the machinery is still in place. The mine has not yet been worked out. It is about 40 feet to the coal. The Lexington Coal Mining Company operate two other mines in the bluff in this township known as the Macy and the Graddy mines. At the latter mine the details of the coal bed are as follows:

XXXVII. Details of Coal Bed at the Graddy Mine.

		Inches.
8.	Limerock	2
7.	Shale, "roof slate"	2
6.	Shale, black	7
5.	Shale, band slate	4
4.	Coal	21
3.	Clay	2
2.	"Sulphur"	8
1.	Clay	22

The drift is equipped with an electric power plant which is used to operate three Sperrey mining machines.

The Lexington Coal Company is the heaviest producer operating within the area. It has a capacity of about 40 cars a day when all the mines are in operation. About one-half of the product is used by the Missouri Pacific railroad, and the rest is shipped to Kansas and Nebraska, as well as to neighboring towns. It is nearly all used for steam-generating purposes.

In the northwestern corner of section 7 (Tp. 50 N., R. 27 W.) and the northeastern corner of section 12, are the two McGrew drifts. At the present time only one of them, the upper one, is operated, the other one being used for an air-course. In these mines the total thickness of black shale between the coal and the limestone cap is 10 inches and the coal

bed is 18 inches thick. The coal lies only 6 feet above the railroad, but one-half mile further west it is reached in a shaft at a level of 15 feet below the track. It soon rises again and at the Carter and Lewis mine, one mile east of Wellington, it is about 10 feet above the railway grade. At the latter place the top shale has a total thickness of 5 inches and the coal, about 18 inches. The coal dips again, and in the eastern part of the town it is reached in the Wellington shaft fully 35 feet below the railroad. The details of the coal bed here are as follows:

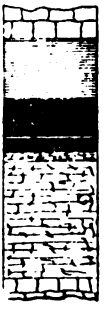
The coal from all these mines is of essentially the same character. It is clean, glossy, black and hard enough to stand transportation very well.

	Inches.
Limestone.....	
Shale, black, fissile	16
Coal.....	7
Shale parting	½
Coal.....	8
Clay, shaly, black.	½
Coal.	8
Clay, pyritiferous.	29
Limestone..	10

Figure 22. Section of Coal Bed at Wellington Shaft.

DEVELOPMENTS ALONG THE CHICAGO, ALTON AND ST. LOUIS RAILROAD.

Along the Chicago, Alton and St. Louis railroad, within the area of the sheet, there are only two mines producing coal on a commereial scale. They are both near Mayview. The Strasburg shaft is one mile east of town and is connected with the railroad by a spur. It is a double shaft, and is equipped with steam-hoisting machinery. The details of the coal bed (section XXXIX) are:



	Inches.
Limestone.....	
Shale, black, fissile	19
Coal.....	11
Parting.	½
Coal.	4
Clay, hard, dirt...	3
Clay, soft, drab...	86
Limestone	6

Figure 23. Section of Coal Bed at Mayview-Strasburg Shaft.

The other shaft is located in the western part of the town. It also is a double shaft and is equipped with steam-hoisting machinery. The coal has been opened by drifting at a number of places on Tabo creek, southeast of Mayview, at different times, but there are now no mines in operation. The Jones and Miller shaft was operated one mile southeast of the town. The output was hauled to Mayview, or sold directly

for consumption in the immediate neighborhood. In the creek valleys north of Mayview a number of mines have been opened, but most of these too are now abandoned, or are worked only during the winter months. Around the head of Brushy creek in the eastern part of township 50 N., R. XXVII W., small drifts are operated during a part of the year and the product consumed in the neighborhood.

SMALLER GROUPS OF MINES.

There are two small groups of mines within the area of the sheet, but none of them produce coal on a commercial scale, none have steam power and none are worked all the year. The first of these groups is in the southwestern corner of township 50 north, range XXVII west. Two of these are the Hill, and the Strafford. The latter is a drift and is located in the southeast quarter of section 30. The details of the coal bed are as follows:

XL. Section of Coal Bed at Strafford Drift.

		Inches.
6.	Limestone	10
5.	Shale, black	17
4.	Coal (top bench)	12
3.	Clay parting	1
2.	Coal (bottom bench)	4
1.	Clay	14

The bed at the Hill drift, 500 yards to the east, is about the same. There has been very recently opened the McFadden drift on the northeast quarter of section 20.

The other group of small mines referred to is in the western part of the sheet in the vicinity of Greenton. There is one shallow shaft and several small drifts. The former, the Armstrong mine, is in the southwest quarter of section 10 (Tp. 49 N., R. XXVIII W.). It is 30 feet deep. The coal is hoisted by horse-power. The output is all used in the vicinity for fuel. The details of the coal bed are as follows:

XLI. Details of Coal Bed at the Armstrong Shaft.

		Inches.
7.	Limestone	12
6.	Shale, black, fissile	16
5.	Clay and pyritiferous shale	1

	Inches.
4. Coal (top bench)	12
3. Clay parting	½
2. Coal (bottom bench)	4
1. Clay	8

The Chamberlain drift is in the bank of the branch about 600 feet northwest of the Armstrong shaft. Another small drift is in the southwest quarter of section 15 of the same township; and still another, the Hook mine, is one and one-half miles south of the former. They are worked occasionally through the winter to supply the local demands for fuel.

North of the Missouri river there is within the area, one mine in operation and several abandoned ones. The Rankine drift is in the northwest quarter of section 8 (Tp. 51 N., R. XXVII W.). The mine is worked most of the year and the product shipped to various points on the Chicago, Santa Fe and California railroad. At Camden, situated on the north side of the river and just outside the western limits of the sheet, coal mining is carried on extensively in the Lexington bed. The coal is reached by shafts from 30 to 50 feet in depth. The coal bed is of about the same thickness and character as at Richmond.

COALS LOWER THAN THE LEXINGTON BED.

The only data obtained showing anything of the character of the rocks below the Lexington coal bed for any distance are the records of the drill-holes in the vicinity of Odessa. These were all churn drill-holes and cannot be implicitly relied upon. If one shaft or diamond drill-hole were sunk in the neighborhood to serve as a check on the record they might be used with a greater degree of confidence.

The thin coal bed lying about 20 feet below the Lexington bed in the vicinity of Lexington is nowhere thick enough to mine profitably. The same bed, exposed on Own creek northwest of Odessa and also struck in the Kirkpatrick well, is still too thin to work. No bed which can be correlated with the Mulky bed of the Higginsville area has been encountered un-

less it be the lower one in the Hatch well, east of Odessa. There is nothing associated with this bed to indicate that it is so, excepting its position with respect to the Lexington bed. The record of the Hatch well agrees reasonably well with the general section and with the Kirkpatrick well still better, but the Wyman well agrees with it not at all. The reported 30-inch seam of coal in the bottom of the shaft is either a local thickening of the lowest beds in the Hatch well or else is a bed not met with elsewhere. At any rate the report needs confirmation. It is indeed quite probable that other and thicker veins may be struck by deep drilling in the area of the sheet. The larger part of the whole thickness of the lower coal measures underlies the rocks outcropping on the surface and as yet is unexplored. It is probable that lower beds will be of small areal extent, but what they lack in that respect may be made up in thickness. This will be on account of the basin-like character of the deposits as the base of the coal measures is approached where shore conditions prevailed during deposition. Prospecting will be more expensive on account of the depth and more extensive in order to locate the various disconnected basins. It must be borne in mind, however, that these conclusions are based upon general considerations and not entirely facts gathered within the area of the sheet.

BUILDING STONES.

Valuable building stone is not abundant within the Lexington area. It may be considered that it does not occur. The limestones occurring near the Lexington coal bed make very good foundations, cellar walls and rip-rap for road building but they will not furnish a good dimension stone.

A sandstone occurring about a mile and a half south of Lexington was used in the construction of a church in Lexington. It proved to be too soft to sustain the weight of the structure and soon gave way. The sandstone bed occurs in the great bed of sandy and clay shales and sandstones lying between the Lexington coal bed with its associated limestones and the Missourian limestones.

The Warrensburg sandstone is available locally.

CLAY DEPOSITS.

The deposits within the Lexington area which can be used in the manufacture of clay wares are the shales, the underclays of the coal beds or "fireclays," the loess and alluvium.

THE SHALES.

Shale beds are encountered in every deep shaft or well and outcrop in many places in the river bluffs and in the hillsides south of Lexington. They occur at intervals throughout the Pleasanton formation as well as in the Clear Fork. The latter are generally below the drainage level, so that they could be mined only by shafts. Those of the Pleasanton formation are all well above the Missouri river level and they can be easily obtained. The shale bed exposed in the bank of Graham branch near Myrick, was sampled by Wheeler, in his examination of the clays of the state and gave the following results:

Color, blue to gray to buff-brown (dry with slight yellow iron stains.) Texture, coarsely lammelar, rather hard (25), fine-grained and uniform. Taste, lean. Slacking took place slowly, but completely to coarse flakes and granules one-half to one-fourth of an inch in diameter. Pyrite was not noticeable; hot hydrochloric acid caused effervesence on a few pieces, giving a yellow color. When ground to 20-mesh and mixed with 23.0 per cent of water, it made a stiff, plastic paste that shrunk 6.6 per cent on drying, and 9.4 per cent when vitrified, giving a total shrinkage of 16.0 per cent. The tensile strength of the air-dried mud averaged 138, with a maximum of 155 pounds, to the square inch. Incipient vitrification occured at 1450° F., and complete at 1600°. It burned to a compact, tough body, when vitrified, that had an excellent dark red color. It rapidly dried and heated without cracking.

A chemical analysis gave:

Analysis of Myrick Shale.

	Per cent.
Silica	54.03
Alumina	22.50
Combined water	7.54
Iron sesquioxide	7.90

	Per cent.
Lime	0.85
Magnesia	2.70
Alkalies	4.12
Total	99 65
Total fluxing impurities	15 57
Specific gravity	2.83

No other tests have been made though there is little doubt that many of the beds in the Pleasanton formation are as good as this one. The sketches given in the preceding pages of this report indicate the distribution of these beds.

UNDERCLAYS (POTTERS' AND FIRE CLAYS).

These include the so-called fire clays underlying the coal bed. There are two of these above the river level, underlying the Lexington coal bed and the one in the Graham branch at Lexington. The bed associated with the Lexington coal is 3 to 5 feet thick. It is grayish in color, rather hard and fine-grained. It is massive and slacks completely on exposure. No analyses have been made of this bed though it is known that it contains too large a percentage of fluxes for making high grade fire brick. It could be used in the manufacture of paving-brick and pottery and other products not required to withstand high temperatures. Its occurrence so closely associated with the Lexington coal bed greatly adds to its value by making the cost of mining it very low and also by furnishing fuel for its burning.

The bed in the Graham branch section is not so thick as that under the Lexington coal. Otherwise its character seems to be about the same as the latter. The cost of mining it will always be much greater than that of the other since its associated coal bed is too thin to bear a part of the expense of mining.

THE LOESS.

The loess clays are abundent over the whole of the area excepting the river bottoms and the higher hills. It is the only clay that is used in the manufacture of building brick. Its quality, quantity and accessibility make it pre-eminently the

brick clay of the Missouri river counties. Its character throughout the whole state is remarkably uniform.

THE ALLUVIUM.

This material is found in all the floodplains of the district. There are two principal phases, an older and a younger. The older phase is usually called gumbo on account of its dark color and sticky character when wet. It occurs in the Missouri river floodplain at a considerable distance from the present channel and in the floodplains of the larger creeks. It is an excellent material for the manufacture of burnt clay for railroad ballast and for road material. The supply is inexhausti ble

The recent alluvium is usually too coarse or too sandy to be used in the manufacture of clay ware.

THE CLAY INDUSTRIES.

The clay industry of the area consists of the manufacture of building brick and draintile. Building brick are manufactured at Lexington where the loess clay is used. The value of the annual product amounts to about $10,000. There are two brick yards, both of them equipped with brick machines.

Building brick and draintile are manufactured at Odessa on a limited scale for local supply. The loess clays and shales of the locality are used.

SANDS.

Sand suitable for building purposes is abundant. The sand from the sandstone of the area is mixed with too much clay to be of much use though it is used to a small extent locally. The sands in the loess are too fine grained and contain too much dark mineral matter which disintegrates readily. It is used in the manufacture of brick, to a very limited extent. There are no beds of glacial sand within the area.

The principal source of supply is the channel sand of the Missouri. It has not yet been utilized though at other points along the river, dredging for it has developed into a profitable industry. The incidental washing that it gets in dredging is

sufficient to make it pure enough for an excellent building sand. The supply is inexhaustible.

WATER SUPPLY.

The water supply is derived from the streams and from shallow wells. The Missouri river does not furnish a very large part of the total amount consumed. Excepting that used in the city of Lexington very little comes from that stream. Lexington derives its supply partly from the river and partly from wells. A considerable part is derived from the latter source. Tabo creek and the two Sniabar creeks furnish water throughout the year. It is used for stock water only, since it becomes very warm in the late summer. The water becomes so low in these streams that the flow almost ceases in August and September. It is always discolored by the matter held in suspension but it contains nothing, either in solution or suspension which renders it unwholesome or unpalatable for stock. The only matter that it holds in solution to any extent is carbonate of lime. The suspended matter is the finely divided material from the shales of the region. They contain no alkaline ingredients that are noticeable. The supply of stock water from the creeks is abundant. The whole of the rural domestic supply and the stock supply as well for the uplands is derived from wells or, in the case of stock water, from reservoirs. The well water is abundant, wholesome, palatable, and readily accessible. Very few wells are more than 50 feet in depth, and the greater number do not penetrate the superficial materials. The loess with the fine-grained sand on which it rests is a reservoir for the rainfall. It is porous and absorbs and retains a large amount of water. If water is not found in the loess it is usually found on a limestone horizon of the Henrietta formations, or in some of the sandstones in the Pleasanton shales.

ROAD MATERIAL.

The road material of the area consists of limestone and material for burnt clay. The limestones available for this purpose are those lying in the hills north of Odessa. Those of

the Henrietta formation outcropping in the river bluffs are too deeply buried to make their extensive use for this purpose profitable. Their quality is fully as good as that of the higher beds and in the eastern part of the area where the higher ones are not available they could be obtained in small quarries at a reasonably light expense. The supply of limestone in the hills north of Odessa is considerable and will in the future be an important source for such material.

Gumbo or the highly plastic alluvial clays, are abundant in the northern part of the area but they have never been utilized for that purpose. The ordinary dirt roads of the loess area where well drained are usually in good condition. They rarely become muddy and never become as soft as the roads over residual clays.

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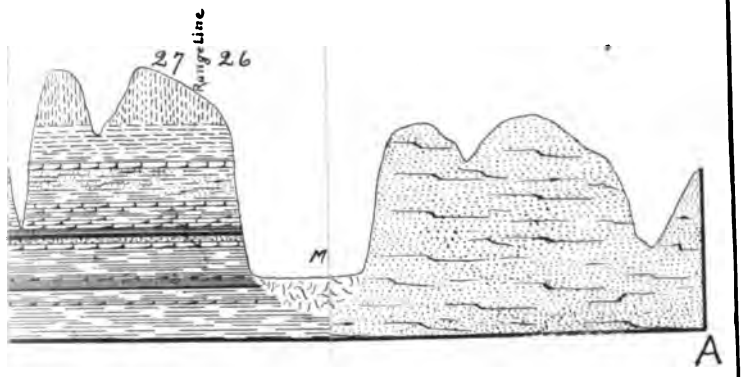
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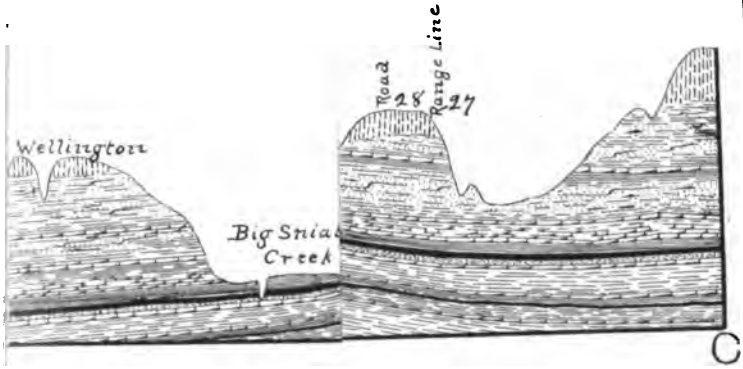
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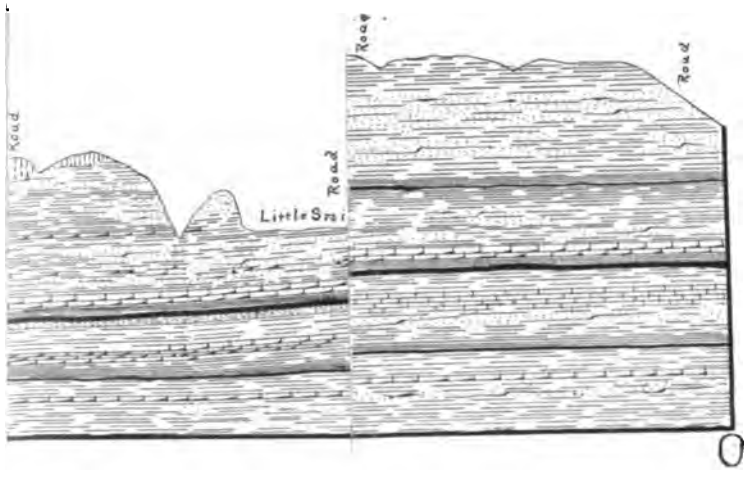
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MISSOURI GEOLOGICAL SURVEY.

CHARLES R. KEYES, State Geologist.

SHEET REPORT NO. 9.

GEOLOGY OF THE

RICHMOND QUADRANGLE,

INCLUDING PORTIONS OF

RAY AND CARROLL COUNTIES.

BY

CURTIS FLETCHER MARBUT.

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GEOLOGY OF THE RICHMOND QUADRANGLE.

BY CURTIS FLETCHER MARBUT.

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INTRODUCTION.

AREA AND LOCATION.

The Richmond quadrangle includes parts of Ray and Carroll counties and is named from the town of Richmond, the county seat of Ray county, situated in the southwestern corner of the area. The territory covered by the sheet is quadrilaterial in shape, of 15′ extent in latitude and longitude, embracing an area of 230.86 square miles.

It is included between the lines 39° 15′ and 39° 30′ latitude and the lines 93° 45′ and 94° longitude west of Greenwich. Its position in the state is northwestern. It lies about 50, 75, 150 and 185 miles from the western, northern, eastern and southern boundaries of the state respectively. It covers nearly the entire eastern half of Ray county and includes a strip of about half a mile of Carroll county along its eastern boundary. The northern line lies a little less than two miles south of the Ray-Caldwell county line; the southern boundary lies about five miles north of the Missouri river, and the western boundary lies about eleven miles east of the western boundary of Ray county.

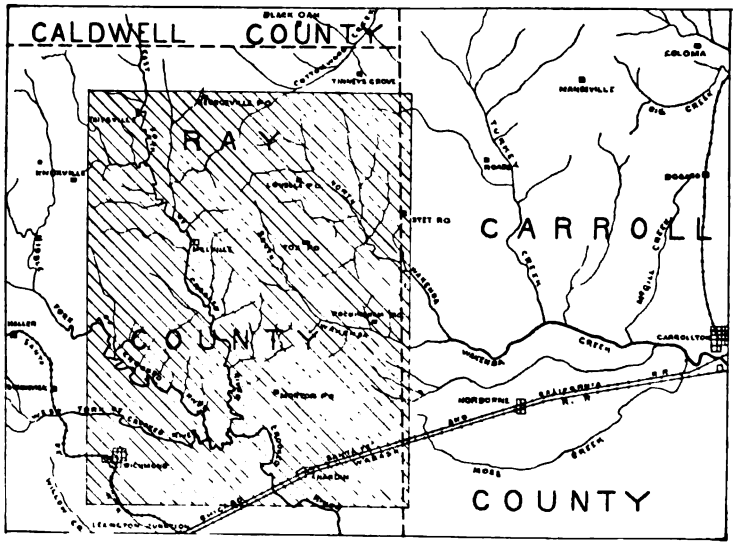

Figure 24—Showing the location with reference to the county lines.

FORMER WORK WITHIN THE AREA.

Ray county was visited by Prof. Broadhead in 1872. A number of sections were measured and described by him and were published in the report of the Survey for 1873; "Iron Ores and Coal Fields." He describes two sections measured on the Missouri river bluffs in the southeastern part of the quadrangle, one on Crooked river two miles north of Richmond, and also a record of shaft No. 6, now abandoned, south of Richmond. Several analyses of coal were made from samples collected by him at this time.

In the Survey office there is on file a manuscript report on the Geology of Ray county, written by Dr. J. Locke. It seems to have been written during the progress of the Swallow Survey. He describes many outcrops occurring along the Missouri river bluffs, but very few occurring elsewhere. Most of this material is incorporated in this report, but the source is stated in each instance.

PHYSIOGRAPHY.

THE REGION IN GENERAL.

A region underlain by gently inclined beds of rock of unequal resistance to erosion will, at maturity, be traversed by belts of lowland and upland, the former being worn out along the strike of the soft beds and the latter being underlain by the hard rocks which are left in relief by the erosion of the softer ones. This will be the result irrespective of the direction of the larger streams of the region. As the cycle of erosion progresses the lowland belts gradually become to be occupied by small subsequent streams which have grown headward along the soft beds from the larger streams. If the differences of resistance to erosion between the hard and soft beds be great, and the beds be crossed by streams which vary greatly in size, the smaller of the original streams may be captured by the subsequent streams and their headwaters diverted by the latter along the lowland through the channel of the sub-

sequent stream and into a larger stream. In this way the lowland may become occupied by large streams which are outlet through the gap in the upland belt occupied by one of the original larger streams. The hard rocks finally become to be respected as a divide by all but the very large streams. The streams are then said to be adjusted. Adjustment does not always take place to a great extent, even when the belts of lowland and highland are well developed. The greater the number of cycles a land area has passed through and the greater the differences of rock resistance, the greater will be the extent of the adjustment.*

The slopes of the highland will vary with and be indicative of the dip of the hard beds. With rather low dips the highland will have one long gradual slope and one short abrupt one. The steep side or surface will face a lowland belt worn on soft beds underlying the cliff maker.

The association of highland and lowland belts, the former characterized by slopes of the kind just described, are characteristic, and represent one type. It has been called the Step and Platform type.†

The topography of the Richmond area, together with that of all northwestern Missouri, is of the Step and Platform type. Northwestern Missouri is traversed in a northeasterly and southwesterly direction by about five distinct physiographic belts. Two of these traverse the area of the Richmond sheet. They are the Warrensburg platform or plain and the eastern part of the Gentry‡ platform, which has neen called the Lathrop upland.§ The Warrensburg plain consists of two belts, the westermost one only, the Holden lowland, occurring in strong development. It enters the State of Missouri from Kansas in southern Cass and the northern part of Bates counties. It trends northeastward and northward to the Missouri river as a belt of undulating country about 45 miles in width. Where it crosses the Missouri river its western border is near Lexing-

*Bull. Geol. Soc. America Vol. VII, pp. 377-398.
†Physical Features of Mo. Mo. Geol. Survey, Vol. X, p. 32.
‡Physical Features of Mo. Mo. Geol. Sur., Vol. X, p. 68.
§Ibid, p. 72.

ton and its eastern, near Glasgow. North of the Missouri its western border trends nearly north, until it becomes obscured by the drift accumulation in northern Missouri. Its eastern border turns sharply eastward after crossing the river, including all the areas of the rocks of the Des Moines formation in northern Missouri. The plain thus widens out until it includes the greater part of north central and northeastern Missouri. Its surface is considerably modified by the drift deposits in this part of the state.

The Lathrop Upland lies west of the Warrensburg plain and the average elevation of its surface is about 200 feet higher than that of the latter. Its eastern border enters the state in Cass county. It trends northward and slightly eastward, passing out of the state into Iowa in Mercer county. The western border of the belt trends northward from near St. Joseph, so that its width is about 50 miles. The belt is sharply separated from the Warrensburg plain on the east by the Bethany escarpment, but it graduates insensibly into the next physiographic belt on the west.

The surface is a broad even-topped upland now dissected by the streams. Its elevation along the eastern border is about 1,100 feet above tide water. The valleys are usually sharply cut into the even upland, and the sides are usually steep. Many of the smaller streams are not yet down to grade and their channels are obstructed in places by blocks of limestone from the valley sides. The contrast between the wide valleys, rounded slopes and undulating surface of the Warrensburg plain and the narrow valleys, steep slopes and even or slightly undulating surface of the Lathrop upland, is marked.

LOCAL PHASES.

The Holden Lowland. Within the area of the Richmond sheet the Warrensburg plain is a lowland of denudation nearly down to grade. The streams are all down to grade and have developed wide floodplains. The valley sides slope gently upward into the rolling or gently undulating surface of the plain. Exposures of rocks rarely occur. Where the large

streams are now cutting into the bluff on one side of their valleys a few feet of rock are usually exposed, though the bluffs are always low and the exposures are thin. The general elevation of the surface of the plain is about 60 to 100 feet above the grade of the larger streams. There are no areas of flat upland into which the streams are gnawing. The surface is made up of graded slopes. Where the Missouri river has truncated one of the subordinate ridges the bluffs rise about 100 feet high, but the slopes are rounded.

The Lathrop Upland. That part of the Lathrop upland included within the area of the Richmond sheet is a thoroughly dissected plain whose elevation is uniformly about 960 feet above tide water. There are a very few small patches of flat upland which has not yet been reached by the dissecting streams. The largest is in the vicinity of Ovid postoffice. That part of the upland represented in our area is only the extremely ragged edge of the large area of it lying west of this. The many branches of Crooked river have cut deep, narrow valleys far back into it, and the narrowing and finally detached remnants extend forward far along the ridges between the streams, usually in such places graduating into the lowland more or less insensibly. The characteristic features of the topography of this plain are the even upland and the narrow, relatively deep and always steep sided valleys in which rock exposures are abundant. It is a topography of rectangular profile while that of the Warrensburg plain is characterized by an undulating profile. The resistant beds which constitute the strength of the upland lie 50 or 60 feet beneath the level of the surface. These beds are underlain by the soft beds on which the Warrensburg plain is developed. All the streams which have cut backward into the upland from the plain have cut through the hard beds and well into the softer ones. The streams easily erode the soft beds, thereby undermining the harder ones and causing them to drop down leaving steep cliffs. In this way many of the streams have opened out cove-like valleys on the soft shales, sometimes of a mile or more in width, which are surrounded on three sides by

steep bluffs. These almost enclosed valleys with their undulating floors and sharp, steep walls constitute the most beautiful feature of the topography.

The Bethany Escarpment. The two divisions of the topography of the sheet are sharply separated from each other by the Bethany escarpment. It is the steep slope by which the surface of the upper drops to that of the lower plain. Its steepness is due to the outcropping edge of the Bethany limestones. The soft shales underlying the limestones weather out rapidly. The limestones are by this means kept continually exposed. They drop off from time to time, keeping the slope steep. The lower plain is advancing westward gradually by the recession of the escarpment. Its domain is increasing while that of the upper, is decreasing. The upper stands, on an average, about 140 feet above the lower plain. The distribution of the physiographic belts over the area of the quadrangle is shown in figure 25.

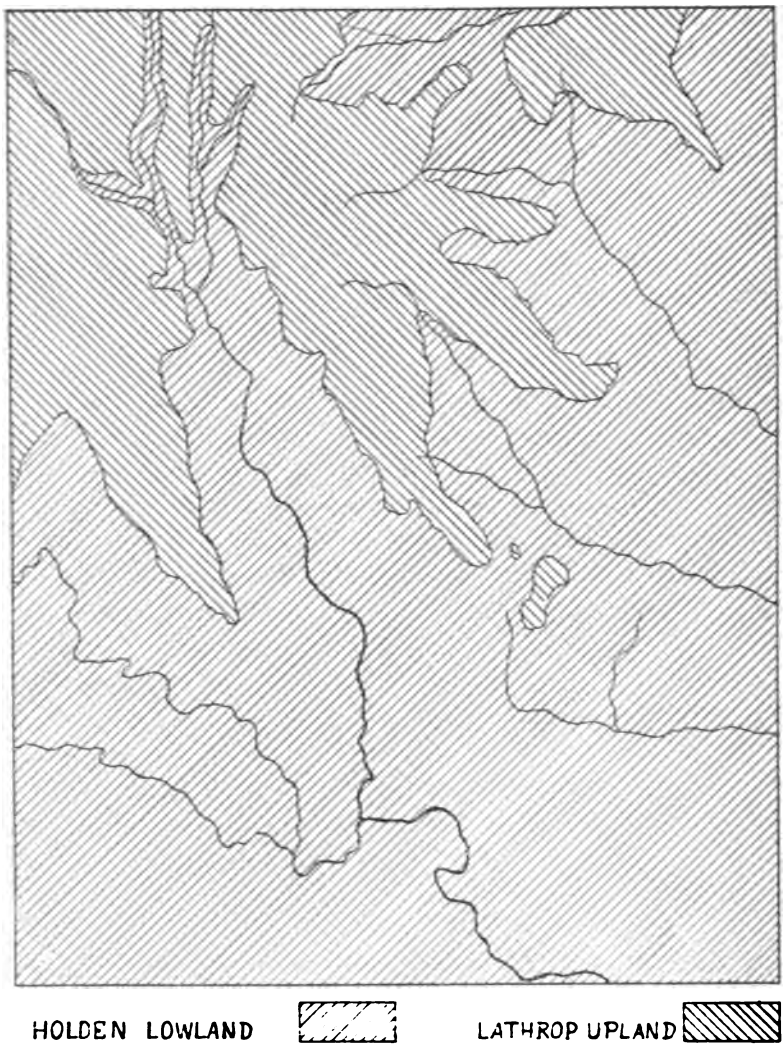

Figure 25. Physiographic belts of the area.

Flood plains. Like a large part of the area of northern Missouri, the flood plains of the streams constitute an important part of the surface of the area. A large area of the broad floodplain of the Missouri river lies within the quadrangle as well as the rather wide plains of Crooked river and Wakenda creeks.

A part of the floodplain of the Missouri river occupies the southeastern corner of the quadrangle. The rest of this section of the floodplain is shown on the Lexington Sheet. The whole plain is, at the eastern side of the quadrangle, about 7½ miles wide and at the western side, where it lies wholly within the Lexington quadrangle it is about 5 miles wide. Up the river it contracts, within a short distance, to about three miles and maintains that width to Forest City in Holt county. Just east of our area it widens slightly becoming a little more than 8 miles in width and then gradually contracts eastward to about 3 or 4 miles. The local widening here is due to the less resistant character of the rocks. Both eastward and westward the river cuts more resistant beds. It consists of a nearly flat plain diversified by occasional ponds, lakes and swamps. Along the northern border of the floodplain lies an almost continuous chain of swamps and shallow lakes. Further out in the plain there are numerous small depressions of a few feet, generally containing water. They are narrow and often in strings. They probably, in some cases, at least mark the course of an old slough. The string of lakes and swamps along the northern side of the floodplain may be due to either of two causes: They may mark the nearly filled channel which the river occupied recently, or they may be the result of a ponding of the surface water along this line by the normal action of the river.

All large streams cut their channels down to their grade in a relatively short time, always reaching it before their lateral streams have invaded the whole of their drainage area and therefore reached their greatest capacity. On account of the fact that the lateral drainage is not yet developed and does not transport to the larger stream as much waste from the land as they do when developed the larger stream cuts its channel down to a lower grade than it can maintain when more detritus is delivered to it by the lateral streams. As a consequence, after maturity is reached and the lateral streams have invaded the whole area and are therefore at their most effective stage, the larger stream, in order to be able to

transport this increased amount of load, has to increase its slope by filling up its valley slightly. The deposition effecting this goes on along the channel of the large stream and results in the formation of a ridge along the crest of which the channel of the stream is cut. (See remarkably clear examples of this action in the lower Mississippi river floodplain shown by the maps of the Mississippi River Commission). The floodplain is therefore highest on the bank of the stream and slopes both ways from it in a direction at right angles to the course of the stream, thereby causing the water to collect along the base of the bluffs. One of the consequences of such action in all large streams is that the lateral streams are not able to maintain their courses across the floodplain up this slope to the large stream, but are forced to turn along the floodplain flowing parallel to the course of the parent stream until the latter crosses to the side of the plain along which they flow and picks them up, or else the water from them becomes ponded along the sides of the floodplain. Applying this to the case in hand, it is seen that Crooked river maintains its way across the floodplain to the Missouri river, but Wakenda and Moss creeks, smaller than Crooked river east of the area of the Richmond sheet, follow the northern side of the floodplain for a long distance before they enter the Missouri, and the drainage from small ravines along the eastern bluffs is ponded at their base. In some of the small lakes near the western side of the sheet it is kgown that they are of recent growth from the fact that they contain the stumps and dead saplings of a young forest which has been killed by the growth of the lakes. Just below where Crooked river enters the floodplain of the Missouri river it is slightly laked. Its channel through the bottoms is not able to carry the water, which seeks discharge through it after a heavy rain. It often floods a large area west of Hardin, and does so even when the Missouri river is at a moderately low stage. The facts therefore seem to indicate that the lakes and swamps along the margin of the bottoms are due to silting up of the floodplain by the Missouri river.

All the principal secondary streams have built floodplains of greater or less width, none, however, reaching a width of a mile. Compared with many of the streams of northern Missouri of nearly equal size, these floodplains are very narrow.

A feature of importance characterizing them as well as that of the Missouri river is terracing. The greater part of these flood plains is built of a massive clay of uniform character, the typical gumbo of the farmers. It is of so compact a character that drainage is imperfect. The surface of this part of the flood plain stands from 20 to 30 feet above the present bed of the stream. It is so high that it is very rarely reached by the highest freshets. Lying from 10 to 15 feet below this in a narrow strip bordering the present channel of the stream is the flood plain of a later period of flood plain building. It is composed of gravel, sand and clay derived from the drift and the country rock. It is the result of the work of the streams at their present stage. Its width is not more than one-thirtieth of the average width of the whole flood plain. The deposits of the first phase were evidently laid down under different conditions than those now prevailing in the area while those of the second phase were as evidently laid down under similar conditions to those now prevailing. The difference in height of the two phases is not easily explained by supposing that a recent warping or uplift of the area has occurred which has caused the streams to cut to a lower level than before the uplift. The slight amount of uplift would not be sufficient to cause such a wide difference in the character of the deposits before and after the uplift. It seems rather to be due to a change in ratio of carrying power of the stream to the load to be carried, and the similarity of the clays of the older phase to the clays of the drift of the region suggests that the explanation is to be sought in that direction. I am not aware that the material of this older phase becomes coarser northward. No direct observations were made with that point in mind. The distribution of the zones of altitude is shown in figure 3.

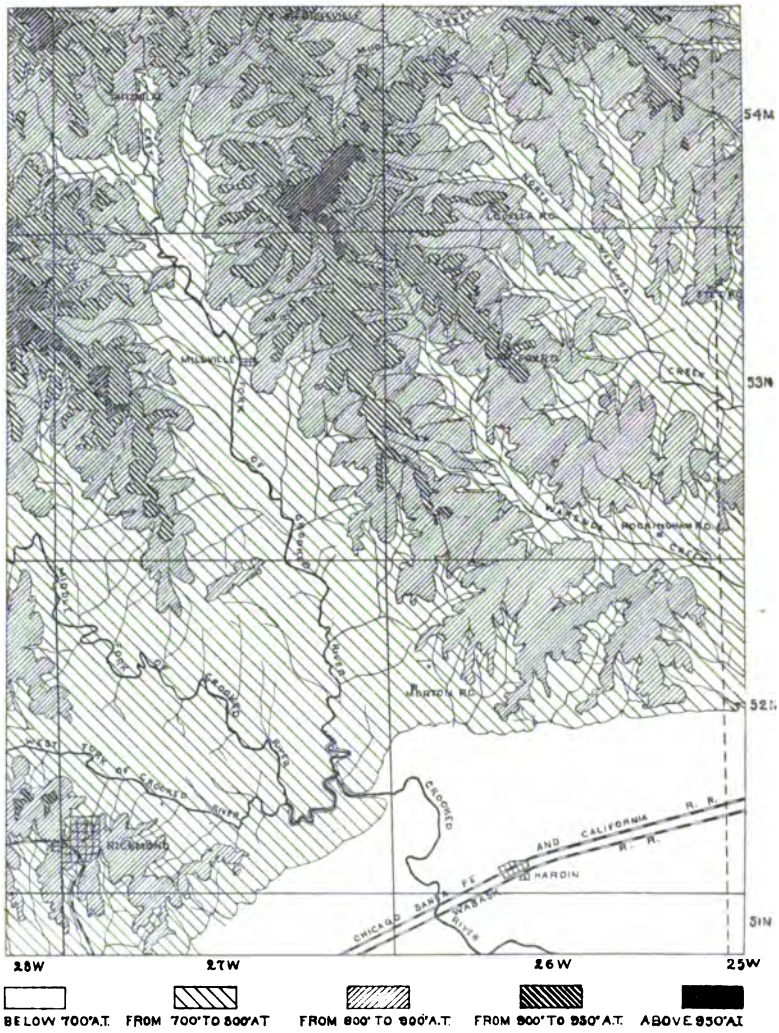

Figure 26. Distribution of Zones of Altitude.

HYDROGRAPHY.

The area lies within the drainage area of the Missouri river, the drainage of the greater part of it reaching that stream directly through Crooked river and Wakenda creek. A small area near the middle of the northern side of the quadrangle is drained into Grand river and thence into the Missouri at Brunswick in Chariton county.

The principal streams are the West, Middle and East Forks of Crooked river and the North and South Forks of Wakenda creek. They are all small streams, carrying during the greater part of the year only a very small volume of water. Their fall is too slight to furnish much power. A few grist mills were located on them when the country was being settled but they were abandoned long ago. The streams flow in channels cut to 15 or 20 feet below the surface of the flood plain now building. The water is always muddy and the bed of the stream is lined with a thick deposit of dark colored mud. Were it not for the steep banks, the deep and muddy channels the largest of the three forks of Crooked river could be easily forded at ordinary stages of the water. But excepting high up on the streams where the beds have more or less gravel and larger rocks derived from the Upper coal Measure limestones they are all crossed by bridges.

The West Fork of Crooked river drains a part of the western part of Ray county extending about 15 miles west of the limits of the quadrangle. The older phase of its flood plain is fairly well developed. There is not so great a difference in elevation of the two phases of its flood plain as on the other forks of the same streams.

The Middle Fork of Crooked river is the largest of the three. It drains a large area of territory extending northwestward in a wide belt to the vicinity of Lathrop in Clinton county, about 35 miles northwest of Richmond.

The East Fork of Crooked river drains an area reaching about 8 miles north of the area of the quadrangle. The two phases of the flood plains are better developed and have a great difference of elevation along this stream than were seen on the others. They are well shown near Millville and northward.

FORESTRY.

The greater part of the area was originally covered with a growth of timber. This included nearly all the area covered by loess, the floodplains of the streams, excepting the swampy

portions, and all the rugged land in the neighborhood of the Bethany escarpment.

The principal forest trees now growing within the area are:

Red oak, *Quercus rubra*.
Black oak, *Q. tinctoria*.
Pin oak, *Q. palustris*.
Laurel oak, *Q. imbricaria*.
White oak, *Q. alba*.
Post oak, *Q. stellata*.
Bur oak, *Q. macrocarpa*.
Shell-bark hickory, *Carya alba*.
Bitter nut hickory, *C. amara*.
White heart hickory, *C. tomentosa*.
Black walnut, *Juglans nigra*.
White elm, *Ulmus Americana*.
Slippery elm, *U. fulva*.
Ash, *Fraxinus*.
Linden, *Tilia Americana*.
Wild cherry, *Prunus Pennsylvanica*.
Wild black cherry, *P. Serotina*.
White maple, *Acer dasycarpum*.
Cottonwood, *Populus monilifera*.
Sycamore, *Platanus occidentalis*.
Hackberry, *Celtis occidentalis*.
Mulberry, *Mores rubra*.
Common locust, *Robinia pseudacacia*.
Honey locust, *Gleditschia tricanthus*.

In addition to these there are a great number of shrubs and small trees such as thorn, several genera and species of which occur; crab apple, wild plum, buckeye, horse chestnut, red-bud, pawpaw, hornbeams, hop-hornbeam, dogwood, persimmon and a great abundance of willow.

The oaks, excepting laurel and pin oaks, are at present almost wholly confined to the rugged lands along the Bethany escarpment and extending back into the plateau a short distance. Along the river bluffs and the more elevated portions of the loess where drainage is fairly good there are a few groves of pin and red oaks. Laurel oaks grow in the wet lands of the river and creek bottoms. In these damp places it is almost the only tree. The predominant oak of the area, excepting on the wet lands, is the red oak. White oak, post and burr oak are very scarce. Hickory is not very abundant. It occurs

in the northern part of the area on the residuary hillside soils along with red oak. There are very few suggestions of "hickory bottoms" within the area; flat, wet bottom lands with a "gumbo" soil in which hickory and pin oak are the predominant trees. The hickory usually occurring in such places is the white heart variety, *C. tomentosa*.

Elm is the most abundant tree occurring on the better drained portions of the loess. It occurs much less abundantly over the whole timbered part. Black walnut occurs only on the well drained soils either on the loess or not. It is not an abundant tree anywhere in the area and those that do occur are of small size. The limestone soils of the hillsides seem to be their favorite habitat.

Cottonwood is an abundant tree in the Missouri river bottoms and occurs less abundantly in the recent floodplains of the other streams. They rarely occur on the older higher floodplains of the smaller streams. The recent floodplains of these streams seem also to contain too much clay and not enough sand for them to thrive. In many portions of the Missouri river floodplain they are the only tree. They are the most abundant along the banks of the stream where the plain is largely sand. Excepting willow they are the first growth to take possession of a recently formed sand bar or sandy island. Sycamore is confined to the river valleys. It is of rare occurrence. It occurs most abundantly in gravely creek bottoms but they find very few such places in this area. A few are found far up on Crooked river where it is cutting the Upper Coal Measure limestones. Linden is a loess soil growth. It is not very abundant. The almost exclusive growth of the recently formed floodplains along the lower courses of the larger secondary streams is maple.

Excepting for local use for fuel and building purposes the timber of the area is not of much importance commercially. There are, however, small areas in which there is yet some timber which can be made into lumber. Along the Missouri

river bluffs west of the mouth of Crooked river, in the valley of Crooked river, the valley of the Missouri along the cosure of Crooked river north of he Wabash railroad and in the rugged portions of the northwestern parts of the area there is some timber still standing, though it is being rapidly cleared away.

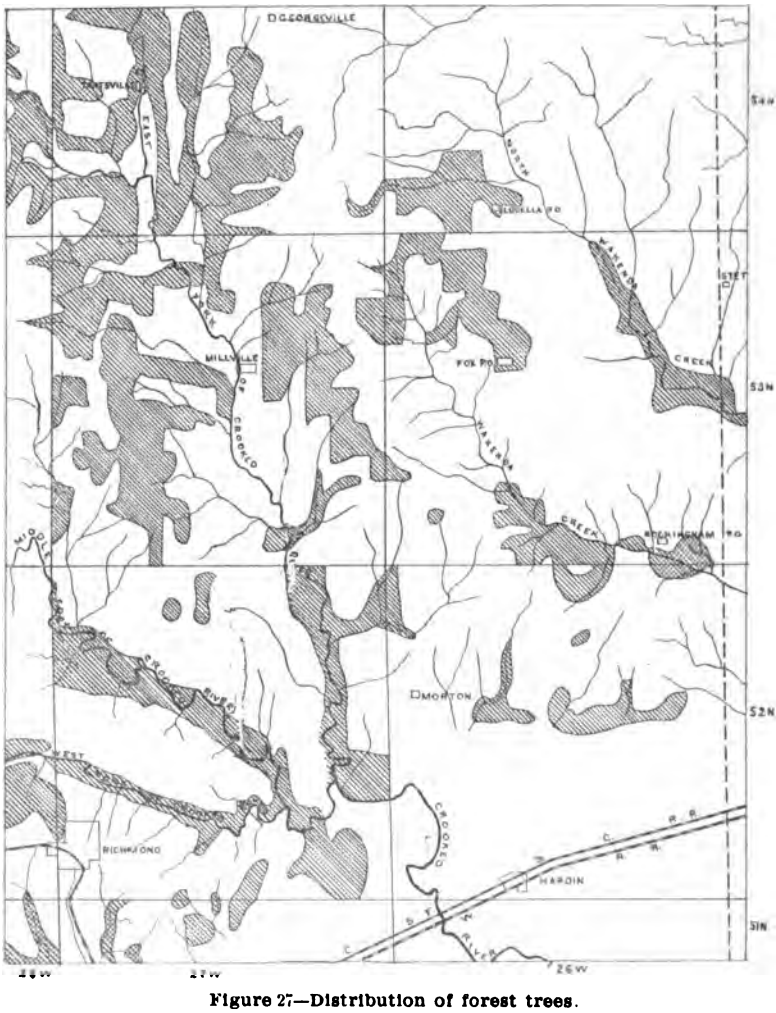

Figure 27—Distribution of forest trees.

GEOLOGY.

GENERAL STRATIGRAPHY OF THE REGION.

The rocks exposed within the area of the Richmond sheet are all sedimentary rocks and belong to the Carboniferous, Pleistocene and Recent periods of geologic time. The indurated rocks are all Carboniferous and belong to the middle of the three great divisions of the rocks of that period. The base of the series is not exposed anywhere within the area but it has been reached in one or two drill holes. These show that it lies about 400 feet below the lowest rocks exposed in the area. The rocks are a part of the Upper Carboniferous or Coal Measure series of Western and Northwestern Missouri. For the whole region they are easily separated on lithologic grounds into about five divisions.

Each division is based upon the prevalence of some one kind of rock. Each therefore marks a stage in sedimentation. They are not usually sharply separated from each other so that a more or less arbitrary line has to be adopted. They are all conformable with each other. This series of conformable Upper Carboniferous rocks is succeeded unconformably in the area of the Richmond sheet by a bed of sandstone and conglomerate, presumably of Carboniferous age.

The Upper Carboniferous rocks of Missouri have recently been divided, under a two-fold classification, into the Des Moines or lower and the Missouri or upper series.

THE DES MOINES STAGE.

The main subdivisions of the Des Moines series in Missouri consist of the Cherokee, the Henrietta and the Pleasanton formations.

The Cherokee shales lie at the base of the Upper Carboniferous rocks of Missouri. In southwestern Missouri more than 250 feet of the formation is exposed. Northward along the strike of these beds the thickness exposed becomes considerably less than that amount. The formation is made up of

shales and sandstones with coal beds and an occasional bed of limestone of limited areal extent.

The Henrietta formation* lies immediately over the Cherokee beds. It consists of shales, limestones, sandstones and clays. It is given a separate classification on account of the limestone beds which it contains. They do not constitute a greater thickness of the formation than any other rock, but on account of their greater abundance here than in adjacent formations and their greater resistance to erosion and wide geographic distribution, the formation deserves separate recognition. It enters the state from Kansas, where each limestone bed has received a separate name, in the western part of Bates county. It trends northeastward through Bates, Henry, Johnson, Lafayette and Ray counties, beyond which it has not yet been traced with certainty. Its course is marked by a line of upland, caused by the greater resistance of its limestones. Its thickness averages about 90 feet. The width of the belt of its outcrop is not so great as that of softer rocks of equal thickness, since so much of its thickness is taken up in hill slope.

The Pleasonton Shales. This formation is one of the best defined and most persistent formations in the Upper Carboniferous rocks of Missouri. It enters the state from Kansas in the southern part of Cass and the northern part of Bates counties. It trends thence northeastward through Johnson, Lafayette, Saline, Ray and Carroll counties, and further northward into Iowa. In the northern part of Missouri it spreads out to greater width than it has further south. South of the Missouri river the width of the belt is about 30 miles.

The formation is made up of shales and sandstone. There are a thin bed or two of coal and an occasional concretionary limestone a few inches thick. The thickness of the formation is about 150 feet.

THE MISSOURI STAGE.

The Upper Carboniferous rocks above the Pleasanton shales have not been subdivided. They include the Upper Coal Measures of the old classification, and probably the Missouri

*Geology of the Calhoun Sheet.

formation of the recent Iowa classification.* In this paper we are concerned with the lower beds of the formation only. The formation as a whole consists of limestones, shales and sandstones, with occasional clay beds and a thin bed or two of coal. None of them are thick enough to mine profitably except locally. Limestones constitute an important part of the formation. Their aggregate thickness is not so great as that of the shales, yet their prominence, on account of their superior resistance makes them an important element in the formation. They range in thickness of beds from a few inches to as much as 30 feet. In the lower part of the formation, that part with which this paper is chiefly concerned, limestone constitutes nearly half the thickness of beds exposed. Higher up in the formation shales become predominant. The limestones are often massive and extensively quarried for construction material at many places. They furnish the foundation stone and much of the building stone for the cities of the northwestern part of Missouri and the northeastern part of Kansas.

The shales of the formation are chiefly argillaceous and bituminous and occasionally sandy. Sandstone is of rare occurrence and the beds are thin. The thickness of the whole series in the state of Missouri is stated by Broadhead† to be about 1,300 feet.

To recapitulate: The upper Carboniferous rocks of western and northwestern Missouri consist of a series of shales and sandstones at bottom from 100 to 400 feet in thickness, a series of shales and limestones overlying this about 90 feet thick. This is succeeded upward by another shale and sandstone series about 150 feet thick, and then comes the great series of limestones and shales of the Upper Coal Measures of the old classification which has a thickness in Missouri of about 1,000 feet. Still higher beds are found in Nebraska.

*Keyes: Geol. Sur., Iowa. Vol. I, p. 85.

†Geol. Survey of Mo. Report on Iron Ores and Coal Fields, 1872, Part II, p. 185.

YOUNGER SANDSTONES.

Under this head is included certain sandstones, shales and conglomerates that are known to occur at several places in the Coal Measures of Missouri. They lie unconformably upon the underlying beds and contain fragments of them, often well rounded. Their contact with overlying beds has never been discovered. They are supposed to be carboniferous in age, though younger than any rocks with which they have yet been seen in association. One of these occurrences is fully described in the report on the Higginsville Sheet,* where Winslow has shown that it occupies an eroded channel in the older rocks.

PLEISTOCENE.

The pleistocene deposits of the region consist of glacial drift in the northern part and loess along the Missouri. The drift reaches a maxium of probably more than 200 feet in the north and does not occur at all in the southern part of the region. The loess occurs along the Missouri river and reaches a maximum of probably 200 feet in thickness.

The Recent deposits consist of the river bottom alluvium found throughout the region.

LOCAL GEOLOGY.

GENERAL SECTION.

All the formations, excepting possibly the Cherokee shales, described above are represented within the area of the Richmond quadrangle. Figure 5 is a general section of the rocks of the area covered. The lowest rocks shown, in fact all those below the underlying limestone of the Lexington coal bed, were not seen within the immediate limits of the Richmond quadrangle but they were seen in the Missouri river bluffs on the south side of the river and only a few miles from the southern limit of this area. From the base of the Warrensburg sand-

*Mo. Geol. Survey Vol. IX, p. 45, 1896

stone downward the formations occur over the whole area with great regularity in thickness and character. In sinking a shaft at any point the rocks encountered will be found to correspond to the general section very closely. The shales lying, in the general section, between the cap-rock of the Lexington coal bed and the first limestone above it are highly calcareous and in some places pass into an impure limestone. In such cases there are 12 to 15 feet of limestone immediately overlying the coal.

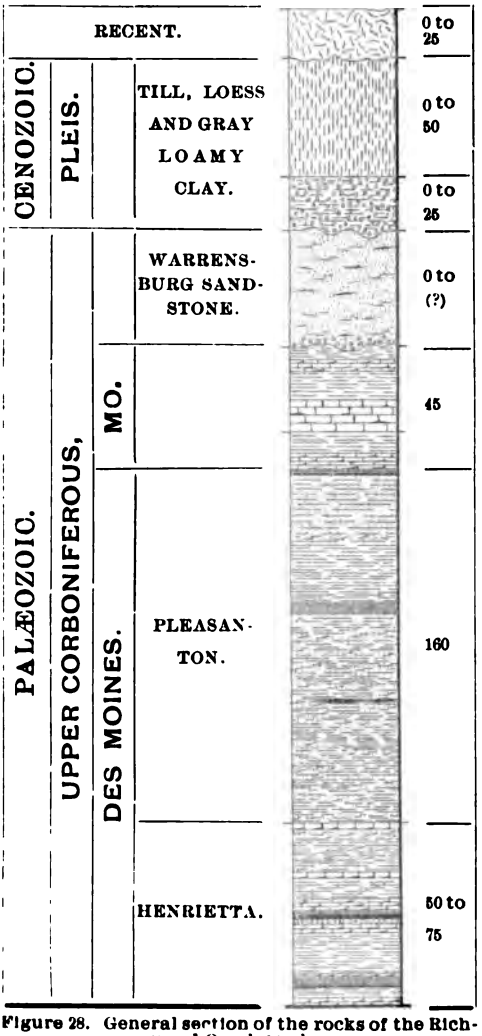

Figure 28. General section of the rocks of the Richmond Quadrangle.

The Warrensburg sandstone is placed above all the coal measure rocks of the area. It was not found in contact with the higher rocks of the formation but the failure to find any line of unconformity between these and the lower beds seems to justify such an interpretation of its position.

The formations occurring within the area are shown in the following table of formations:

Table of Formations.

	Recent.	Alluvium.	
Cenozoic.	Pleistocene.	Gray Loamy Clay and Loess.	
		Till.	
Palæozoic.	(?)	(?)	Warrensburg Sandstone.
	Upper Carboniferous.	Missouri Stage.	Bethany Limestone.
		Des Moines Stage.	Pleasanton.
			Henrietta.
			Cherokee (?)

STANDARD LOCAL SECTIONS.

The upper line of delimitation of the Cherokee shales has never been followed in detail north of Henry county. It is known in a general way that the limestones associated with the Lexington coal bed in Ray county correspond to the Henrietta formation of Henry and Bates counties, but just where the dividing line between this formation and the Cherokee shales lie in the former county has not yet been determined. It is fairly well established that the line of separation lies not far beneath the Lexington coal bed. There are no data at hand, however, that give any indication of the exact distance or even the approximate distance, so no attempt is here made to establish the line.

If the Cherokee shales outcrop in the area of the Richmond quadrangle at all, there can be but a few feet, and these must occur in the river bluffs in the extreme eastern part.

At the eastern side of the quadrangle the Lexington coal bed lies less than 40 feet above the level of the river bottom and no rocks are exposed below it. The rocks outcropping within the area of the quadrangle dip gently northwestward. They are not otherwise disturbed from their original position.

The angle of dip is so small that to the eye the beds appear to be horizontal. The Lexington coal bed, in the southeastern part of the quadrangle, is about 725 feet above the tide level. In the vicinity of Richmond, 12 miles west, it is about 700 feet, and at Sater's shaft, near the northern line of the sheet, it lies about 670 feet above the same level. The direction of steepest dip is apparently west of north and the amount is about five feet to the mile. All the beds are conformable, so that this may be taken to represent the average dip.

The Henriatta Formation. This formation in the area of the Richmond sheet includes the series of limestones and shales which are associated with the Lexington coal bed. Geographically it represents a small part of the area, but from an economic point of view it is a very important formation. It outcrops in a narrow belt along the bluffs of the Missouri river and extends up the valleys of the larger streams. A section of the formation about 85 feet thick is exposed in the area of the sheet. It is made up of limestones and shales with one coal bed and a clay bed. From 20 to 30 feet of the total thickness is limestone. Section I compiled from the record of shafts in the vicinity of Richmond, and from outcrops at other places, shows the general relations and thicknesses of the rocks of the formation.

I. Section of Henrietta Formation.

		Feet.
1.	Limestone	5
2.	Shale and Sandstone	30
3.	Limestone	6
4.	Shale, highly calcareous, often passing into limestone	8
5.	Limestone	8
6.	Shale, clay and coal *(Lexington Coal)*	4
7.	Limestone	5
8	Shale	about 15

The beds of this formation persist in character and thickness over a large area in Ray, Lafayette and Caldwell counties. They have been studied in Lafayette county and found to extend over the northern part at least, with no significant change whatever excepting that the calcareous shale, number 4 of Section I, becomes less calcareous southward. The persist-

ence down the dip of the beds is apparently not so great. The indications are that they soon change in character in this direction.*

The Pleasanton Shales. The outcrop of this formation occupies a large part of the area of the sheet. It occupies all that part designated as part of the Warrensburg plain, in figure 24 excepting the river bottoms and a narrow strip along the bluffs of the Missouri river. It underlies the surface of at least 90 square miles of the quadrangle. The thickness of the formation is about 160 feet. It is almost wholly made up of sandstones and shales. The sandstones graduate into sandy shales and these into clay shales along the strike of the beds. There are one or two thin beds of coal in the formation, none of them more than 6 inches thick, but they are not persistent in thickness over the whole area. The beds change along the strike so rapidly that the horizon of any particular bed cannot be traced very far.

A general section of the formation compiled from a number of outcrops, wells and shafts at different places in the area of the sheet is about as follows:

II. Section of Pleasanton Formation.

		Feet.
1.	Shale, argillaceous, reddish	20
2.	Shale, sandy and argillaceous, brown and yellowish	80
3.	Coal	½
4.	Shale, sandy	25
5.	Sandstone	5
6.	Shale, blue and red, argillaceous	80

All the beds are soft. They are consequently easily eroded and the area of their outcrop is a lowland nearly down the grade. They readily decompose so that they are covered with a deep soil. The area underlain by them is the seat of the agricultural wealth of the region. They were worn down so low before the glacial invasion of the region that their surface received a thick coating of the loess or waterlaid drift which constitutes the best soil of the state. Nearly the whole of their surface is under cultivation. In some places in the area

*A. Winslow, Mo. Geol. Sur., Prelim Report on Coal, p. 114.

of the sheet a six-inch bed of coal forms the top member of the series. It is often concealed but it appears to be rather a persistent member, not only here but elsewhere in western Missouri.

The Missourian Series. The rocks belonging to this formation occupy the uplands of the northern and northwestern parts of the sheet, with a few outliers in the vicinity of Richmond and in the divide between Crooked river and Wakenda creek. The formation is made up of about equal thicknesses of limestone and shale. The limestones occur in strata from 3 to 8 feet thick and occasionally in massive beds. They are the most resistant rocks in the region, and their fragments cover the hillsides and lie in the beds of the ravines in great abundance. They are highly fossiliferous, though the fossils are not easily worked out of the matrix without breaking them. They are relatively pure, are usually fine-grained and bluish in color and are occasionally subcrystalline.

The shales are argillaceous and sandy and occasionally bituminous.

Section III is a general section of the rocks of this formation which occur within the limits of the Richmond sheet.

III. Section of Missourian Beds.

		Feet.
1.	Shale	10
2.	Limestone	8
3.	Shale	10
4.	Limestone	12
5.	Shale	15
6.	Limestone	5

The Warrensburg Sandstone. In the Missouri river bluffs on the county line, in the southeastern corner of the sheet, is an exposure of sandstone, conglomerate and limestone, showing a clear unconformity between the sandstone and conglomerate and the underlying limestone. The exposure lies just at the western edge of the sandstone belt and shows a very coarse red sandstone containining pebbles of limestone exactly similar to the coal measure limestone near it. Tongues of a coarse conglomerate made up almost entirely of limestone pebbles,

most of them being water-worn pieces of the fossil chætetes multipora, extend into the sandstone. The actual contact between the limestone and the conglomerates was not seen though they were exposed within a few feet of each other. Figure 24 from a sketch made at the locality is a diagrammatic section of the outcrop.

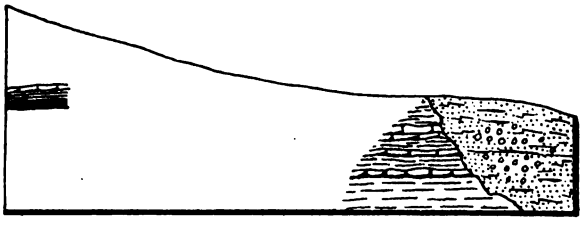

Figure 29.

This is the only exposure of this kind seen within the limits of the sheet. East of this several miles a sandstone is quarried in the Missouri river bluffs. North of this within the area of the quadrangle no rocks are exposed excepting superficial material. We feel justified in correlating this with the Warrensburg sandstone described in the report on the Higginsville sheet* of this survey and also in the report on the Lexington quadrangle which lies immediately south of the Richmond. Its distribution beneath the floodplain of the Missouri river is purely hypothetical. No data whatever are at hand showing where it exists and where it does not exist.

Pleistocene Deposits.—The Pleistocene deposits of the area include the drift and the loess. There are few places in the area of the sheet where drift occurs. No occurrence of typical till has been noticed. There are a few places in which a yellowish clay, filled with well rounded northern pebbles, is found. There are no deposits of subangular bowlders such as characterize the drift of the northern states. Small beds of sand occur occasionally.

The loess is the most important of the post Paleozoic formations. It covers all the area of the Warrensburg plain lying

*Mo. Geol. Survey, Vol. IX, p. 45.

within the sheet to a considerable depth. Todd* states that the thickness reaches a maximum of nearly 100 feet. He states that it occurs on the highest uplands of the area though its thickness is not great. It is a brown loam here as elsewhere in the state. Its general characteristics have been described so often that there is no necessity of repeating the description here.

Alluvium. Alluvium occurs in the floodplains of all the larger streams. It forms a considerable proportion of the total area of the quadrangle. It exhibits two phases, an older and higher one, and a newer and lower. The older phase constitutes by far the larger area. The greater part of the floodplains of Crooked river and the Missouri are made up of it. The newer phase occurs only as a rather narrow fringe on each side of the present stream channels. The older phase is a dark sticky clay, too close in texture to allow good drainage. It is the gumbo of the farmer. The younger phase is coarser in grain, is more porous, and lies 10 feet lower than the other. The older phase is usually treeless, while the newer is always heavily timbered. The thickness of the older phase on Crooked river is as much as 25 feet and may be more since its base has been seen nowhere.

DETAILED DESCRIPTION OF DATA.

Outcrops along the Missouri river bluffs and in township 52 N., ranges 26, 27 and 28 W.

The lowest beds exposed within the area outcrop along the bluff in the eastern part of the sheet. Most of the sections described by Mr. Locke and recorded in a manuscript now in the survey office will be copied here. Most of them are from localities along the bluffs.

*Mo. Geol. Sur. Vol. X, p. 147.

IV. Record of Outcrop

(Ne. ¼ of Sw. ¼ of section 13, township 52 N., range 26 W.) From J. Locke.

Base of outcrop is about 690 feet A. T.

		Feet.
	Interval from top of Pleasanton Shales	140
1.	Concealed	25
2.	Limstone, fine grained, gray with a decided greenish tinge. Weathers into shelly pieces.	2
3.	Concealed	19
4.	Limestone, hard, rather fine-grained, bluish gray and gray decomposing to a buff color. Chaetetes abundant	5
5.	Shale, argillo-calcareous with thin irregular beds of impure blue and light buff limestone. Contains Chonetes mesoloba and Ch. Flemingi	10½
6.	Limestone, dark blue, weathering buff	2½
7.	Shale, bituminous, sometimes entirely wanting	½
8.	Coal, bituminous, with a 2-inch seam of clay five inches from the top *(Lexington bed)*	1 to 2
9.	Clay	1
10.	Concealed	18

About 1,200 west of the last locality Mr. Locke measured the following section:

SECTION V.

Record of outcrop (Nw. ¼ of the Sw. ¼ of Section 13, Township 52 N., Range 26 W.). From J. Locke.

Bottom of Section is about 690 feet A. T.

		Feet.
	Interval from top of Pleasanton formation	135
1.	Concealed	28
2.	Limestone, gray, with greenish tinge, becomes shelly on exposure *(Top of Henrietta Formation)*	12
3.	Concealed	32
4.	Limestone, bluish gray.	4
5.	Concealed on which were found fragments of rock similar to No. 6 of Section IV.	
6.	Limestone, hard, blue	2½
7.	Shale, bituminous.	1½
8.	Coal *(Lexington bed)*	1 to 2
9.	Clay	2
10.	Concealed	8

A short distance further west Mr. Locke found the same rocks exposed. Here he states that the place of No. 6 of

Section IV is sometimes taken by a bed of a clay. He also states that where the shale of No. 7 thins the coal thickens.

In the W. ½ of the Ne. ¼ of the Se. ¼ of Section 14, Township 52 N., Range 26 W., Mr. Locke measured the following section:

VI. Record of Outcrop.

		Feet.
	Interval from top of Pleasanton Shales, about	100
1.	Concealed, about	85
2.	Limestone, earthy, gray, with olive tinge, shelly, weathers to a bluish color	1
3.	Concealed	2
4.	Sandstone, brown	11
5.	Concealed	7
6.	Limestone, gray, with greenish tinge *(Top of Henrietta formation)*	2
7.	Concealed	20
8.	Limestone, hard, bluish-gray and gray	4
9.	Shales, argillo-calcareous with beds of impure limestone	11
10.	Limestone, dark blue	2½
11.	Coal *(Lexington bed)*	1¼
12.	Concealed	6

Since Mr. Locke's report was written a shaft has been sunk near the middle of the east line of section 15, township 52, N. range 26, W. It is now operated by Mr. W. Evans. He reports the following record:

VII. Record of W. Evan's Shaft.

Top of shaft is about 770 feet A. T.

		Feet.
	Interval from top of Pleasanton Shales, about	120
1.	Superficial material	80
2.	Rock *(Top of Henrietta formation)*	1
3.	Shale, argillaceous	6
4.	Sandstone	8
5.	Limestone	2
6.	Shale	6
7.	Limestone	17
8.	Shale, black fissile	¼
9.	Coal *(Lexington bed)*	¼-2
10.	Clay	2-4

West of this the slope of the bluff becomes gradual and is covered with a mantle of loess which hides the underlying

Paleozoic rocks. On the south side of the hill in the northern part of section 25, Township 52, N. Range 27, W. a limestone is exposed about 15 or 20 feet above the level of the flood-plain of Crooked river. We correlate it with the cap-rock of the Lexington coal bed.

In the S. W. ¼ of Section 26, Township 52 N., Range 27, W., the Lexington coal was mined several years ago in the bank, of Crooked river. Southward and westward along the bluffs from this place the coal was not seen nor any of the rocks associated with it. Its horizon line has been placed on the map but it was done on the assumption that it lay at about the same elevation as at its last outcrop to the east. It is exposed at the Rankine mine a short distance along the bluff southwest from where they cross the southern line of the sheet.

In the S. E. ¼ of the S. E. ¼ of Section 29, Township 52, N., Range 27 W., the coal was reached by a shaft at the time of Mr. Locke's examination of the region. The record is as follows:

VIII. Record of Shaft. From J. Locke.

		Feet.
	Interval from top of Pleasanton shales about	125
1.	Soil and subsoil	8
2.	Sandstone, at lower part passing into sandy, then argillaceous shales	26
3.	Limestone, bluish, gray, weathers to a ferruginous stained buff *(top of Henrietta formation)*	4
4.	Shale, argillaceous, drab	8
5.	Limestone, top part contains thin strata of shale like No. 4. The upper four feet are of a bluish gray color, the lower three feet being blue	7
6.	Shales, bituminous	½
7.	Coal *(Lexington bed)*	1
8.	Clay	2½

Shaft No. 6 of the Richmond Coal Company is located in the S. W. ¼ of the S. W. ¼ of Section 31, Township 52 N. Range 27 W. It was abandoned several years ago but the following record, copied from Prof. Broadhead's report, was obtained from Mr. Hughes when the shaft was in operation. It is as follows:

IX. Record of Shaft No. 6, from G. C. Broadhead.

Top of shaft is about 790 feet A. T.

		Feet.
	Interval from top of Pleasanton shales, about	100
1.	Soil	2
2.	Clay	12
3.	Sandstone	4
4.	Shale, blue	9
5.	Shale, red	16
6.	Limestone and flint (?) *(top of Henrietta formation)*	5
7.	Soapstone and slate	2½
8.	Sandstone, white	6
9.	Lime and sandstone	5
10.	Soapstone	8
11.	Slate	
12.	Fireclay	2
13.	Flint rock *(is limestone)*	5½
14.	Shale	
15.	Slate	4
16.	Limestone, dark gray	5
17.	Slate	¼
18.	Coal (generally 2 feet) *(Lexington bed)*	2¼
19.	Fireclay (6 to 8 inches)	1½

The records of shafts Nos. 3, 4 and 5 reported to the writer by Mr. John Gibson, the superintendent, show the same rocks, excepting the absence of the top beds on account of their location on lower ground.

The shale No. 17 is not uniformly three inches thick. It varies often in the same mine from nothing up to about 8 inches. The coal varies in thickness also but not very much.

About 600 feet southwest of shaft No. 6 a new shaft was sunk during the summer of 1894 by the Diamond Coal Company of Richmond.

At the time of the last visit to the region, June, 1894, it was down to a depth of 65 feet. The owners expected to strike the coal at about 20 or 25 feet lower. The limestone No. 6 of the last section was struck here at a depth of 25 feet and was 5 feet thick. Below this were 22 feet of sandy micaceous shales and soft sandstones.

Underneath this the shaft had passed through 12 feet of agillaceous shales and was still in them.

Shaft No. 7, operated by Hubbell and Co. of Richmond, is located in the N. E. ¼ of the N. E. ¼ of Section 36, Township 52 N., Range 28 W. The following record was reported to the writer by Mr. John McCart, the superintendent:

X. Record of Shaft No. 7.

Top of shaft is about 800 feet A. T.

		Feet.
	Interval from top of Pleasanton shales, about	75
1.	Soil and clay	23
2.	Shale, red	4½
3.	Shale, blue	11
4.	"Hard rock," bluish *(limestone) (top of Henrietta formation)*	4½
5.	Shale, blue	30
6.	"Hard rock"	4
7.	Shale	15
8.	Limestone cap rock	7
9.	Coal *(Lexington bed)*	2 1-6
10.	Clay	1½

It will be noticed in comparing sections IX and X that No. 6 of the former corresponds to No. 4 of the latter, that the interval between Nos. 6 and 13 of the former and 4 and 6 of the latter is about the same in both, but that the interval thence to the Lexington coal bed is 12 feet in the former and 22 feet in the latter. Whether this is due to an error in reporting the records, or represents the facts we cannot say. The following record, however, should be of more authority on the particular locality in which it is located than either of the last, even for their locality. It is of Shaft No. 12 sunk recently by the Richmond Coal Company. It is located just outside the limits of the sheet on the railroad about two miles west of Richmond. The record was kept by Mr. Gibson, the superintendent, and reported to the writer by Mr. Ferguson of the company.

XI. Record of Shaft No. 12.

Top of shaft is about 815 feet A. T.

		Feet.
	Interval from top of Pleasanton shales, about	60
1.	Superficial material	16
2.	Sandstone	14
3.	Clay, red	10
4.	Shale, blue	18
5.	Shale, red	17

		Feet.
6.	Limestone (*top of Henrietta formation*)	8
7.	Clay	6
8.	Shale, blue	19
9.	Coal streak	
10.	Clay	4
11.	Limestone	6
12.	Shale and clay	5
13.	Limestone	6
14.	Coal (*Lexington bed*)	2
15.	Clay	2

A shaft was sunk during the past summer* at the roadside about 400 feet southwest of the bridge across the west fork of Crooked river a mile north of Richmond, by Messrs. Dixon and Stewart. The rocks encountered, below the superficial material, were the same as those in the last section from No. 11 to the bottom of the shaft. The limestone corresponding to No. 6 of the last section is exposed in the road about 25 feet above the top of the shaft. The black fissile shale between the cap-rock and the coal is here only about two inches thick. The same parties sank a shaft a few hundred feet south of this to the horizon of the Lexington coal but found no coal.

North and northeast of Richmond, south of the line between Townships 52 and 53 the surface is so thickly covered with loess that exposures of indurated rocks are very rare.

In Section 2, Township 52 N., Range 27 W., the Lexington coal bed has been operated in two places but the shafts are so shallow that no Coal Measure rocks above the cap-rock of the coal bed were encountered.

In the S. W. ¼ of the N. E. ¼ of Section 22, Township 52 N., Range 27 W., the following section was measured by the writer:

XII. Record of Outcrop.

Top of section is about 725 feet A. T.

		Feet.
	Interval from top of Pleasanton shales, about	200
1.	Limestone	5
2.	Coal, with a very few inches of black fissile shale above it. (*Lexington bed*)	2
3.	Clay	1½
4.	Limestone	3-4
5.	Shale	

*Summer of 1895.

In the N. W. ¼ of the N. W. ¼ of Section 15, Township 52 N., Range 27 W, is a well in which a hard rock was struck at a depth of 27 feet. The top of the well is about 745 feet A. T. It is probably the cap-rock of the Lexington coal bed. Half a mile west of this a limestone outcrops in the bank of Crooked river.

SECTIONS IN TOWNSHIP 53 N., RANGES 26, 27 AND 28 W.

In the eastern part of Township 53 N., Range 26 W., very few exposures of country rock occur. The country is covered with a thick bed of loess and glacial till. Along the streams occasional exposures of sandy and argillaceous shales and thin sandstones occur. Toward the western part of the township in the vicinity of Fox, and westward the limestones of the Upper Coal Measures are exposed. The details of the occurrence of these limestone beds here was not determined but it may be safely assumed that they differ in no material respect from the same beds north or west of this. In the N. W. ¼ of Section 8 a thin bed of coal was struck in a dug well located near the top of the ridge.

This is the first occurrence so far of the Ovid coal which is placed by Broadhead about 2 feet below the top of the Middle Coal Measures. It is about six inches thick and outcrops at many places north and west of this.

In the next township west of this the rocks of the Upper Coal Measures are abundantly exposed in the steep hollows and along the hills limiting the plateau, though the softer beds of the Middle Coal Measures are generally concealed. The fact that they are generally concealed thereby showing their less resistant character is of some value as evidence that their character is essentially the same as in the vicinity of Richmond.

In the road running westward through the middle of the W. ½ of N. W. ¼ of Section 13, Township 53 N., Range 27 W., the following succession was seen. The thickness could not be made out exactly but the succession was well shown and may be relied upon.

XIII. Record of Outcrop.

Top of section is about 910 feet A. T.

		Feet.
1.	Concealed from hilltop	
2.	Limestone, fossiliferous, about	8
3.	Shale and concealed, about	12
4.	Limestone *(Bethany Falls)*	10
5.	Concealed	14
6.	Limestone	?
	Interval to top of Pleasanton shales	15

No. 2 contains a great number of fossils but they cannot be obtained in good condition.

No. 4 is the massive spotted limestone known in some parts of northwestern Missouri as the "Spotted rock." It was named by Broadhead the Bethany Falls limestone on account of the fact that Big creek flows over it in a cascade at Bethany in Harrison county, Missouri. It is one of the most persistent beds in northwestern Missouri.

It is known to occur in many counties, reaching from Lafayette, Cass and Johnson counties on the south to Harrison county on the north the latter being one of the northern border counties of the state. It maintains almost identically the same lithologic character along this whole distance. Westward it has been traced to Kansas City and a short distance beyond but beyond this the dip carries its horizon below the drainage level of the country.

From the top of the hill about 1500 feet east of Millville to the bed of Crooked river at the bridge in Millville the following rocks were seen. The thicknesses are determined principally from the topographic map:

XIV. Record of Outcrop.

Top of section is about 880 feet A. T.

		Feet.
1.	Concealed	
2.	Limestone, about	6
3.	Shale, about	12
4.	Limestone, about	7
5.	Shale, sandy and argillaceous	70
6.	Concealed, about	45
7.	Shale, sandy with interbedded thin sandstone	25

The top of the Pleasanton shales is at the base of No. 4. The thin bed of coal marking it was not seen in this section, though there is no necessity in supposing it to be absent. The rocks immediately overlying it could very easily have hidden it. It is exposed in the road in the N. E. ¼ of Section 10, Township 43 N., Range 27 W., about a mile and a half north of Millville.

In the road in the middle of the S. E. ¼ of Section 19, Township 53 N., Range 27 W., the rocks exposed are about as follows:

XV. Record of Outcrop.

Top of section is about 910 feet A. T.

		Feet.
1.	Concealed, about	10
2.	Limestone, about	8
3.	Concealed, about	12
4.	Limestone *(Bethany Falls)*	7
5.	Concealed	15
6.	Limestone	4
	Interval to top of Pleasanton shales.	2

The concealed intervals may be very safely referred to shale beds.

Where the road crosses the branch at the school house about a mile southwest of this place a sandstone about one foot thick is exposed in the channel.

In the vicinity of Dockery P. O. a limestone is exposed at an elevation of about 750 feet A. T. which we correlate with No. 6 of Section XV.

In the road at the S. W. corner of the N. E. ¼ of section 25, Township 53 N., Range 28 W., the succession is about as follows:

XVI. Record of Outcrop.

Top of Section is about 880 feet A. T.

		Feet.
1.	Limestone	
2.	Shale, dark, about	10
3.	Limestone *(Bethany Falls)*, about	8
4.	Shale and concealed, about	20

The base of this outcrop is near the top of the Pleasanton shales.

Less than half a mile south of this another bed of limestone lies about 25 feet below the equivalent of No. 3 of this section. We correlate it with the limestone lying at the base of the Missouri formation.

The interval between them at the latter locality is made up of argillaceous shales brown and reddish in color the latter occurring near the top, the former lower down.

SECTIONS IN TOWNSHIPS 54 N., RANGES 26, 27 AND 28 W.

On the Ross land in the S. E. ¼ of the S. E. ¼ of Section 22, Township 54 N., Range 26 W., a well was dug through the following rocks according to Mr. Ross:

XVII Record of Dug Well.

Top of the well is about 805 feet A. T.

		Feet.
	Interval from top of Sniabar shales	40
1.	Soil and clay	21
2.	Shales	42
3.	Coal	½
4.	Shales	

The well digger reported a layer of hard rock overlying the coal. If so it is probably a hard, sandy layer of the shale. It is not too high, however, for the limestone No. 6 of Section XV if it does not dip northward. There is no coal bed under it near Richmond however.

In the S. E. ¼ of the N. E. ¼ of Section 35, Township 54 N., Range 26 W., the following rocks are exposed in the road:

XVIII. Record of Outcrop.

Top of section is about 900 feet A. T.

		Feet.
1.	Concealed, about	10
2.	Limestone, about	14
3.	Shale, black, about	⅔
4.	Limestone, breaks into rhomboidal blocks, fossiliferous	3
5.	Limestone, weathers to buff color	6
6.	Smut *(top of Pleasanton shales)*	½
7.	Shales, sandy	25
8.	Sandstone, about	2
9.	Shale, argillaceous, exposed	25

In the S. W. ¼ of the S. E. ¼ of Section 13, Township 54 N., Range 27 W., is a shaft on the Sater land. No complete record could be obtained. The top of the shaft is about 25 or 30 feet below the base of the Bethany Falls limestone which is well exposed in the sides of the hollow on both sides of the shaft. The following record was patched up from what Mr. Sater and one of his miners remembered of the rocks passed through:

XIX. Record of the Sater Shaft.

Top of shaft is 819 feet A. T. (spirit level).

		Feet.
1.	Soil and clay, about	20
2.	Shale	6
3.	Shale, black	8
4.	Shale, red	9
5.	Shale	4
6.	Sandstone	8
7.	Limestone and shale with some black shale, about	40
8.	Sandstone	9
9.	Limestone	5
10.	Shale	1½
11.	Limestone, about	10
12.	Shale, black fissile	1¼
13.	Coal *(Lexington bed)*, about	2
14.	Clay	4

The top of the shaft is near the top of the Pleasanton shales.

In the N. E. ¼ of the N. E. ¼ of Section 36, Township 54 N., Range 27 W., a deep churn drill hole was bored, about the year 1868, for oil. No record could be obtained but there is a tradition current among the people of the neighborhood that a bed of coal was struck about 150 feet from the surface and another one about 50 feet below this. The top of the well is within a foot or two of the top of the Pleasanton shales, here about 840 feet A. T. The coal is therefore about 690 feet A. T. The coal bed in Sater's shaft is about 680 feet A. T. The first bed struck therefore is probably the same as Sater's coal which has been correlated with the Lexington coal bed. The interval between the two coals in the drill hole corresponds very closely with that between the Lexington and Mulky beds in Lafayette county.

In the Ne. ¼ of the Se. ¼ of section 32, township 54 N., range 27 W., the following rocks are exposed in the bank of Crooked river:

XX. Record of Outcrop on Crooked River.

Base of outcrop is about 855 feet A. T.

		Feet.
1.	Sandstone, shaly, about	4
2.	Shale, becoming darker near bottom, about	85
3.	Limestone, dark in concretionary masses	½
4.	Shale, blue	4

No. 4 reaches to the water in Crooked river. It is reported that a bed of coal about 6 inches thick is exposed in the bed of the river when the water is low.

At the middle of the north line of the Ne. ¼ of section 18, township 54 N., range 27 W., the following section was measured:

XXI. Record of Outcrop.

Top of outcrop is about 875 feet A. T.

		Feet.
1.	Limestone *(Bethany Falls)*	16
2.	Clay, dark (shale)	8
3.	Shale, black fissile	8
4.	Limestone	1-6
5.	Clay	½
6.	Limestone, highly fossiliferous	1-6
7.	Clay	½
8.	Limestone to creek	1

GEOLOGICAL STRUCTURE.

Concerning the structure of the area there is very little to say. Like all the rest of Missouri the rocks lie essentially horizontal. There is a slight general dip northwestward, amounting to a decline of about 150 feet from the southeastern corner to the northwestern corner of the quadrangle. A few extremely slight undulations are shown on the map, but they are barely perceptible.

West of this the limestones of the Missouri formation are exposed in every ravine.

The details are rarely shown and the general succession is so uniformly the same as has been already described that further description is unnecessary.

ECONOMIC GEOLOGY.

The deposits of economic importance at present within the area are soils, coals, clays, building stones and road material.

SOILS.

The soils of the area are of two kinds, residuary and foreign.

The residuary soils are confined to very small patches and are unimportant. They occur only on the steep hillsides of the northern part of the quadrangle and are thin on account of the activity of erosion. They are, however, very fertile when of sufficient thickness to give room for plant roots. The great variety of the underlying rocks and the fact that the larger part of them are limestones, will explain the fertility of these soils. Very little or none of this soil is under the plow; the land being too rugged and steep for that purpose where it occurs. It is used for pasture and grasses, especially blue grass which grows luxuriantly.

The foreign soils of the area are of two kinds according to their origin; those derived from alluvium and those derived from drift. The soils derived from alluvium constitute rather an important part of the area. They include all that part of the area lying within the Missouri river bottom and those in the floodplains of the other streams. The soils of the Missouri river bottoms are exceedingly fertile and, where they are well drained, produce heavy crops of corn or wheat. So far no strong and united effort has been made to drain these lands and therefore a considerable part of them are uncultivated or are in such a condition that the yield is small. As will be seen from the map, a considerable strip along the edge of the bluff through almost the whole width of the map is unfit for cultivation on account of sloughs, though a considerable portion of this is utilized for pasture. The soils of the better drained portions is a dark sandy loam of several feet in thickness. That of the poorly drained portions is a black "gumbo" which is soft and sticky when wet and hard when dry. The

increased blackness of this soil is due to the accummulation of only partly decomposed vegetable matter whose complete decomposition is prevented by the water.

A very small part of these lands is subject to overflow even during the times of high water in the Missouri river. The alluvial soil of the lower valleys of the other streams is essentially of the same character as those of the Missouri river bottoms. There are yet considerable areas of these lands uncultivated on account of lack of drainage.

The soils of the "second bottoms" or the former floodplains of the upper course of Crooked river are not so valuable as those of the present floodplains. They are less sandy and though higher above the river, the drainage is no better. They are underlain by a light colored clay which prevents sufficient under drainage.

Besides the lack of drainage in these soils they do not seem to have the chemical constituents of a fertile soil. In the vicinity of Millville and southward these soils have been beneficially modified by the limestone soils washed from the adjacent hills.

The soils derived from drift are of two kinds. Those from the drift proper or till and those from loess.

Those derived from loess are the most important both in extent and fertility. It is a reddish, porous pulverulent loamy and generally well drained soil. It is the source of the agricultural wealth of the area, and is almost all under cultivation. It reaches to an altitude of about 900 feet A. T. and covers an area of about 100 square miles.

The soils from the drift proper occur on the highlands in the northern and northwestern part of the quadrangle. While they are not so fertile as those from the loess yet they constitute a good soil where there is a good thickness of them. They are clean, easily cultivated and very well drained. They constitute the original prairie area of the sheet. These are only outlying patches of the great stretch of drift soil prairie extending over northwestern Missouri. During the last few years considerable interest has been manifested in drainage and a

considerable amount of tiling has been laid under limited areas, such as a line passing in a circle around the head of a little draw in the loess area. This has been an experiment but the result has been so favorable that we may expect a great extension of the use of tiling in the future. In the Missouri river bottoms tiling will have to be used in connection with ditching in order to drain the soil sufficiently.

COAL.

There is one bed of workable coal known to underly the greater part of the area of the sheet. This is known as the Lexington bed, so named from the town of Lexington, about 8 miles southeast of Richmond just across the Missouri river. The workings are all located along or near the edge of the floodplain of the Missouri river.

There are four or five small openings now operated in section 13, township 52 N., range 26 W. They are all drifts and are worked only for local domestic consumption, excepting two of them which are owned and operated by the Ray County Coal, Brick and Tile Company. The coal from these is used for steam production at their works at Lake View P. O. The easternmost one of these mines is operated by Mr. Henry Rogers. He states that the coal runs from 12 to 22 inches in thickness but it is oftener 12 inches than 22. It is very irregular in thickness at all these mines, not only does the top coal run out and come in again but the bottom coal also runs down to almost nothing in places. There is very little slate, as a general thing, the top rock lies directly on the coal. At Bucklin's drift in section 16 the section, according to the owner, is about as follows:

XXII. Details of Coal bed at Bucklin's coal bank.

		Inches.
1.	Limestone	
2.	Shale, black fissile	6
3.	Coal, top bench	6
4.	Clay	2
5.	Coal, bottom bench	19
6.	Clay	

At Houston's bank the section is essentially the same as at Bucklins.

At William Evan's shaft in the eastern part of section 16 the following section of the coal bed was reported by the owner:

XXIII. Details of Coal bed in Evan's Shaft.

		Inches.
1.	Limestone	
2.	Shale, black, fissile	8
3.	Coal, top bench	6
4.	Shale parting	8
5.	Coal, bottom bench	18
6.	Clay	24 to 40

Mr. Evans says coal often runs down to a thickness of only six inches.

Farther west in the same section two drifts are now operated one by Mr. C. L. Smith and the other by Mr. W. M. Phillips. The section of the coal at Smith's bank reported by the owner is so nearly the same as that in Evan's shaft that it is unnecessary to insert it here. The only difference is that Mr. Smith reports no overlying shale between the coal and the cap-rock.

A drift was once operated about 600 feet west of Smith's and also one in the N. W. ¼ of section 21, township 52 N., Range 26 W., but both are now abandoned. There are a great many more openings along the bluffs that have not been noticed but none of them were in operation at the time of inspection (June, 1894.) Many of them are worked during the winter for fuel for local consumption. The most important mines within the area of the sheet are in the neighborhood of Richmond. Three coal companies mine coal on a large scale for shipment, while several smaller shafts are operated for local consumption.

Shafts Nos. 3, 4 and 5 operated by the Richmond and Camden Coal Co., are all situated on the St. Joseph branch of the Sante Fe R. R. and all near the center of section 6, Township 51 N., Range 27 W. They are all double hoists, operated by steam power and well equipped for handling the coal. A large number of men are employed during the whole year.

The cap-rock of the coal forms an excellent roof for mining. There is very little slate, running from nothing to 3 or 4 inches. The coal bed is about two feet thick, occasionally reaching as much as 27 inches. It occasionally varies slightly in thickness but is rarely less than 20 inches. There is a top coal of from 3 to 8 inches and a bottom coal pretty uniformly 18 inches thick, separated by a shale band about 2 inches. An analysis of the coal, not from any one of these shafts but from No. 6 situated in the S. W. corner of Section 31, Township 52 N., Range 27 W., now abandoned, was made by Mr. Chauvenet and published in the Report of the Survey for 1872, Part II, p. 67.

It is as follows:

Water	8.15
Volatile matter	37.60
Fixed carbon	46.35
Ash	7.90
Sulphur	4.17

The new shaft of the Diamond Coal Company is situated in the southeastern corner of section 36, township 52 N., range 28 W. It was sunk during the past summer of 1894, and the owners intended to commence operating the mine about August 1st. It is a double hoist shaft and is equipped with steam machinery for handling the coal. It was the intention to start with a capacity of about 100 tons a day. A spur about 500 feet long connects the shaft with the railroad. At the time of inspection the shaft was not down to the coal.

Within a mile west of Richmond along the railroad are shafts Nos. 7, 8, 9, 10 and 11. Owned and operated principally by local capitol. No. 7 is a steam-power, double hoist shaft 95 feet deep, owned and operated by Wm. Hubbell & Company of Richmond.

No. 8 is also equipped with steam hoisting machinery and is owned by Mrs. Wm. Wilson. No. 9 is owned and operated by the Richmond Coal Company. It is a single hoist shaft and has horse-power hoisting machinery.

No. 10 is similarly equipped and is operated by the Diamond Coal Company, while No. 11 is equipped with steam hoisting machinery and is owned and operated by Pickering and Son.

At No. 10 the following section of the coal bed was measured by Mr. Winslow*:

XXIV. Details of Coal Bed in Shaft No. 10 at Richmond.

		Inches.
1.	Limestone *(cap-rock)*	
2.	Shale (occasionally present)	2-3
3.	Coal *(top bench)*	4-5
4.	Shale, parting	1-2
5.	Coal *(bottom bench)*	18
6.	Clay	14-20

They are all near the railroad and are connected with it by short spurs. They all produce coal for shipment. It is shipped to St. Joseph and local points on the railroad and is used almost exclusively as a steam producer. The railway consumes a considerable amount in locomotives.

The Diamond Coal Company operated a single hoist shaft in the northern part of the town of Richmond. Its output is consumed in the town for domestic and steam-producing purposes. A shaft about 80 feet deep is owned and operated by Hasting and Douglass in the eastern part of Richmond. The details of the coal bed according to a miner are here as follows:

XXV. Details of Coal Bed in Hasting and Douglass' Shaft.

		Inches.
1.	Cap-rock *(limestone)*	
2.	Coal *(top bench)*	5-6
3.	Clay, parting	2
4.	Coal *(bottom bench)*	20
5.	Clay	12

The coal is hoisted by horse-power and is all consumed in the vicinity.

Mosely and Daugherty operate a shaft about a mile east of town and Pat Walsh one about a mile and a half northeast of town. Both are operated by horse-power and the product is consumed in the vicinity.

During the past summer of 1894 a shallow shaft was sunk near the bridge over Crooked river about a mile north of Richmond. It is owned and operated by Messrs. Dixon and Stewart and depends upon local demand for the disposition of its output.

*Report Mo. Geol. Survey. Prelim. Report on Coal, 1892, page 111.

The Sater shaft in the northern part of the sheet near Ovid post office is operated for local trade only. The following section was reported:

		Inches.
1.	Limestone	156
2.	Shale, black, fissile	15
3.	Coal	6
4.	Shale	2
5.	Coal	15

The Lexington coal bed according to the evidence gathered in and around the area of the Richmond sheet may be considered to underly the greater part of the area. It has been traced along the bluff from near the eastern side of the sheet to the western side. It was not traced to the eastern limit on account of the decrease in altitude of the bluffs which brought their top below the horizon of the coal bed. If this were not the case it is probable that the coal would be cut out in the area of the sandstone which we have correlated with the Warrensburg Sandstone and certainly should, if our correlation is correct. Toward its eastern outcrops the coal becomes very irregular in thickness becoming so very much so that in many places it is unprofitable to mine it. It is not known certainly to occur on the bluffs east of this point on this side of the Missouri river. On the south side of the river it extends several miles east of this.

For the northern and northwestern part of the area we have not very abundant data though what we have is significant. Sater's shaft and the old oil well two miles south of it show its presence there and the shaft at Cowgill about 5 miles north of Georgeville P. O. shows its extension in that direction.

An attempt was made several years ago to sink a shaft to the coal from the Crooked river bottoms about a mile south of Taitsville. The shaft was sunk to a depth of about 80 feet and a churn drill hole was bored 15 feet deeper from the bottom of the shaft. It is reported that coal was struck and that it was 30 inches thick. This is about the horizon of the Lexington coal, but the occurence of the coal seemed to be more of a rumor than a well established fact. The whole work was

done by a farmer. The facts are given for what they are worth. Toward the eastern part of the sheet on the northern side of the area the coal seems to disappear again. Several years ago a shaft was sunk in Mud creek valley, about a mile north of Tinney's Point P. O., situated just outside the northern boundary of the sheet in section 2, township 54 N., range 26 W. The top of the shaft according to the reports of its location is about 760 feet A. T. The location was not seen by the writer. It is reported that at the supposed horizon of the Lexington coal bed only 2 inches of coal was found. The record from 8 feet above this horizon to the bottom of the shaft was reported to the writer by a miner who worked in the shaft. It is as follows:

XXVII. Record of Old Tinney's Point Shaft.

		Feet.
1.	Limestone	8
2.	Coal *(Lexington bed)* (?)	1-6
3.	Clay	4
4.	Limestone	2
5.	Shale	10
6.	Sandstone	14
7.	Shale, black, fissile	5
8.	Coal	½
9.	Clay	8

The shaft was 110 feet deep and if the top is at about the elevation given above, the first thin coal bed is at about the horizon of the Lexington coal bed.

Due north of Tinney's Point about six miles, at Braymer, a drill hole was put down in search of coal but none of workable thickness was encountered anywhere near the horizon of the Lexington bed.

Taking these facts into consideration it seems probable that the Lexington coal bed thins out before reaching the eastern side of the quadrangle. At least the evidence is of such a character as to suggest extreme caution in investing money in shafts in this part of the area. The presence of the coal should be proved by drilling before expensive shafts are commenced.

Concerning the evidence given by the shaft at Tinney's Point it must be borne in mind that its significance hinges on

the elevation of the top of the shaft. If its top is more than 60 feet above where I have placed it, its story, so far as the Lexington coal bed is concerned, has no significance. Mud creek floodplain north of Tinney's Point is about 750 feet A. T.

Concerning coal beds below the Lexington bed we have the data furnished by the old oil well near Ovid in which a thin bed was reported about 50 feet below the Lexington bed. We have also the evidence of another deep drill hole, bored with a churn drill in the N. E. ¼ of the N. E. ¼ of Section 34, Township 52 N., Range 29 W., several miles west of our area. The well was bored for oil under the supervision of Mr. H. H. Beeson who reported a record to Broadhead*.

In this, coal occurred in the borings at a depth of about 150 feet below the Lexington coal bed; but Prof. Broadhead says the coal is mixed with pyrite, zinc blende and carbonate of lime.

Again coal occurred about 20 feet below this but was again mixed with pyrite and blende. Below this to the base of the Coal Measures no further occurrence of coal was reported.

The top of a thick series of limestone which without much doubt are Lower Carboniferous in age was struck about 650 feet below the base of the Bethany Falls limestone, showing the thickness of Coal Measure rocks beneath the Lexington coal bed to be about 435 feet. This may be considered the average thickness of these rocks below the Lexington coal bed within the area of the Richmond quadrangle.

Whether the occurrences of coal noted in the latter drill hole become purer and are of workable thicknesses within the area cannot be stated. The evidence is not of a totally negative character and need not be considered of a kind to discourage careful prospecting.

It will be useless to go deeper than about 450 feet below the Lexington coal bed.

*Report Mo. Geol. Sur., 1872. Iron Ores and Coal Fields, Part II, p. 84.

BUILDING STONE.

The limestones of the Upper Coal Measures are quarried in the vicinity of Richmond for cellar walls, foundation stone and for road metal. The stone occurs in beds of sufficient thickness for this purpose but not sufficient for dimension stone. Stone has not been used to any great extent for building purposes within the district. The towns are built either of brick or wood. The limestones of the northern part of the quadrangle are probably more heavily bedded. They have never been quarried at all. The loose flat fragments lying abundantly over the hillsides supply all the demand for stone by the farmers. None of the sandstones in the Pleasanton formation are hard enough for good building stone. The limestones associated with the Lexington coal bed are no better for building purposes than those higher up in the series.

CLAYS.

The deposits which are capable of being used for the manufacture of clay products consist of shales, underclay of the Lexington coal, loess and gumbo of the river bottoms.

Shales. There seems to be two more or less persistent beds of shale in the Pleasanton formation which could be utilized as clay. Neither of the beds have been so used, though the character of the deposit leaves little doubt as to such a possibility. One of the beds occurs near the base of the formation. It was penetrated in all the shafts in the vicinity of Richmond and was described as a bed of blue and red shale, the upper, or blue part being about 10 feet, and the lower bed being about 15 feet in thickness.

The other bed lies at the top of the formation and consists of a reddish or purplish clay occuring in a bed about 20 feet thick.

It is extremely probable that other beds occur locally in this formation though none were seen.

Under Clays. Only one bed of this kind occurs within the area of the sheet. It is about 18 inches thick and under-

lies the Lexington coal bed. It has not been utilized here though the same bed has been used in the manufacture of draintile at Corder in Lafayette county. Its occurrence along the river bluffs, at a considerable depth beneath the surface will greatly retard its development. No analyses have been made of this bed for this area though it is probably too calcareous for use in the manufacture of firebrick.

Loess. The loess occurs abundantly over nearly the whole area of the sheet. It is used at Richmond for the manufacture of building brick. It possesses its usual characteristics and is an excellent brick clay.

Gumbo. Gumbo clays are abundant in the area. They occur in the floodplains of all the larger streams. The supply in the Missouri and Crooked river valleys is inexhaustible. They are utilized at Hardin for the manufacture of building brick and at Norborne a few miles east of the sheet, they are burned for railway ballast. They have been used for the manufacture of draintile at Norborne also.

WATER SUPPLY.

The local water supply comes from wells, springs and creeks. Artesian water has never been sought. The nearest flowing well is at Clinton in Henry county.

The creek and river water is abundant for uses to which it is put. It serves for stock water only. In the upper branches of Crooked river which flow over the limestones of the northwestern part of the area the water is usually clear. Soon after the shales of the Pleasanton formation are entered the water becomes muddy. The streams are down to grade and flow very slowly so that they can carry only the finest silt. This is furnished abundantly. Even at the lowest stage of the water when very little silt is carried into the larger streams, the water always looks dark. This is due not altogether to the matter in suspension but is due partly to the reflection from the muddy bottoms of the channel in which the streams flow. The discoloration does not render the water unwholesome nor unpleasant to the taste.

Crooked river and its principal branches, and Wakenda creek are perennial streams. The other small creeks are dry during the greater part of the summer.

Springs. There are no large flowing springs in the county. At numerous places there is a slight outflow at the outcrop of a permeable layer of rock. The principal horizon of such outflow is at the top of the Pleasanton shales. These beds are usually impervious to water. The rainfall on the overlying limestones percolates downward until the shales are reached. It then flows along their upper surface to where they outcrop. Such places are usually marked in springtime by bogs in which the mud is too soft to hold the weight of a horse. The outcrop of the sandstone beds of the Pleasanton formation is indicated in the same way. These springs if they may be called such, do not furnish sufficient water at any one place for the formation of streams. If a barrel is sunk into the soil at such a place it usually fills with water forming a "gum" spring. During the dry weather of the late summer these places dry up.

Wells. The domestic water supply of the region is obtained almost altogether from this source. A small percentage is obtained from cisterns. Where the superficial deposits are as much as 30 feet deep they rarely have to be penetrated before water is encountered. When water is not obtained from these deposits it is obtained whenever one of the limestones of the region is struck or in one of the sandstones of the Pleasanton formation.

As a whole pure and wholesome well water is very easily obtained anywhere within the district. It usually contains carbonate of lime in solution, but rarely anything else.

CLAY INDUSTRIES.

The local clay industries consist in the manufacture of building brick at Richmond and Hardin and of draintile and brick at Lake View postoffice. About 500,000 bricks are manufactured annually and are used to supply the local demand only. At Richmond the loess clay is used entirely. At Har-

din, gumbo is used. The Ray County Clay, Brick and Tile Company at Lake View postoffice uses loess and the underclay of the Lexington coal bed in the manufacture of brick and tile. This company has erected a plant of considerable capacity equipped with good machinery and is located within a few feet of the outcrop of the Lexington coal bed and its under clay. Loess clays occur on the bluffs at the works and gumbo within a few hundred feet. They are favorably located for the use of three of the principal kinds of clay in the county.

LIME.

Lime is not manufactured within the district. The limestones of the northwestern part of the area as well as those of the Henrietta formation, could be utilized for the manufacture of a dark but otherwise fairly good lime. The same beds are used in the vicinity of Kansas City, and other beds of the same character at St. Joseph, for making lime for local use.

SAND.

The supply of sand is not important. There are no important beds of glacial sand, and the sandstones are too argillaceous to furnish a good material for building purposes.

ROAD MATERIAL.

The road material consist of burnt gumbo and broken limestone. Gravel beds do not occur in any of the streams and the glacial beds are too thin and argillaceous for the purpose. The only resource excepting burnt gumbo is the limestone beds. These as already shown occur in great abundance but they have not been utilized for the purpose. Their utilization would require considerable expense for a crusher and for quarrying, so that the cost of the material ready for use would be so great that its use would be practically prohibited. The gumbo can be burnt much cheaper and would probably be as good as the soft limestone. The clay and the coal for burning it occur in great abundance and close together. The subject of good roads has not been agitated much yet. So it is not probable that either of these materials will be utilized for road making for some time to come.

INDUSTRIES.

AGRICULTURE.

Agriculture is by far the most important in capital invested, the number of men to which employment is furnished and in the amount and value of surplus product.

The soil is so uniformly fertile over the whole area that there is not a definite localization of the various branches into separate districts. Indian corn is the staple for the whole area. Wheat is grown to a considerable extent but it is of subordinate importance to corn. A corollary to the corn growing branch is the stock raising and feeding branch of agriculture. All the corn produced is fed to stock at home. Large amounts of it are imported from surrounding areas for feeding also. Cattle and hogs are almost exclusively the stock raised and fed. Feeding stock is much more extensively carried on in the area than raising it, the latter branch of the industry being carried on where land is not so valuable for grain growing and where cheap pasturage can be had. Excepting parts of the Missouri river bottoms and small areas of broken land near the Bethany escarpment the area is preeminently grain growing.

Vegetables and fruits are grown for home consumption only. The soil grows vegetables well but cost of transportation to market is too great to encourage their cultivation for city markets.

MINING.

The mining industry is confined principally to the vicinity of Richmond. All the mines producing coal for shipment being located there.

The mines along the bluffs near the eastern side of the quadrangle are worked for local domestic consumption only, excepting for what coal is consumed at the Tile Works at Lake View P. O. Sater's shaft in the northern part of the area is worked altogether to supply the local demand for fuel.

During the year ending June 30, 1893, Ray county produced 319,405* tons of coal, a large part of it being from the mines near Richmond. The number of men employed averaged 1083 during the winter months and 607 during the summer season.

Of these all but about 225 men were employed in the mines of the area of the Richmond quadrangle.

ROADS.

Before the construction of the railroads which now traverse the area the important roads were few in number but these were more important then than any are now. They were the roads leading to the principal steamboat landings on the Missouri river. For the area of the Richmond quadrangle Camden was such a point. It is situated on the Missouri river bluffs about five miles southwest of Richmond. At Camden the river leaves the northern side of its floodplain and flows directly across it to Wellington in Lafayette county. Eastward it follows the southern side of the floodplain for a long distance.

From this area the roads leading to Camden were therefore the important ones.

Richmond is at the diverging point of the roads running north and northeastwardly. From Camden to Richmond there is one road and over this all the traffic for a large area passed. At Richmond this road separated into three branches; one running north to Knoxville and Kingston; one running up the East Fork of Crooked river to Millville and beyond and a third running due east from Richmond to Crooked river, then following the Missouri bluffs to Morton and then striking into the country. The first, the Knoxville road was the line of communication for a larger area than the others since it led directly to the wide prairies north of the area. The Millville road passed through a rich territory all the way from Richmond to Millville. The Morton road also led into and through a fer-

*These figures as well as those giving number of men employed were taken from the Report of the State Mine Inspector for the year ending June 30, 1893, p. 87.

tile region. These three roads as well as their trunk line from Richmond to Camden all follow very nearly their original courses across the country. The Knoxville road crosses the upland plain in an almost direct line northward from Richmond, excepting where it is diverted, on approaching Crooked river, to Dockery P. O. where it turns to a spur of the plateau up the slope of which it climbs to the top. It then follows the top of the plateau to Knoxville and beyond. The Millville road follows very nearly its old course. In a few places it has been diverted to the land lines. The Morton road also follows its old course with no diversion at all unless it be at Morton.

The newer roads of the area follow the land lines excepting along the rugged portions near the escarpment limiting the plateau. Here they follow the ravines or ridges and seek gradual slopes for ascent to or descent from the plateau.

Since the construction of the railroads across and near the area the old roads have lost their old time importance while many of the new roads have become more important than any of the old ones. The surplus products of the southeastern quarter of the area now find a shipping point at Hardin and of the southwestern at Richmond, while the towns on the Chicago, Milwaukee & St. Paul railroad running east and west a few miles north of the sheet have absorbed the traffic from most of the northern part of the area. No one line of road therefore is the traffic line for a large area.

The roads are all built of the ordinary loess drift and residuary clays of the area. During dry weather and when frozen they are good. When thoroughly wet they are almost impassable.

During a few weeks in the spring they often become practically impassable excepting for a footman or a horseman. Very little attempt has been made to build solid road beds of gravel or broken stone on account of the great expense. They are used by the farmers over which to haul their products to market. Fortunately during the spring season, when they are in their worst condition the farmers have little use for them. The taxpayers therefore do not feel justified, under present conditions, to incur the great expense that would be necessary to macadamize them.

RAILROADS.

Three railway lines traverse a small portion of the area.

The Chicago, Santa Fe and California and Wabash railroads run through the Missouri river bottoms across the southeastern part of the area. The St. Joseph branch of the Santa Fe system, or, as it is sometimes called, the St. Joseph, St. Louis and Santa Fe railroad crosses the southwestern corner.

The Chicago, Santa Fe and California railway is a trunk line between Kansas City and Chicago, passing in an almost direct line across the state of Missouri. It is the line over which the large number of Santa Fe lines west of Kansas City and St. Joseph send their through freight to Chicago. It follows the Missouri river bottoms from Carrollton about 10 miles east of the area of the quadrangle to Kansas City.

The Wabash railway is a main line of that system from Kansas City to St. Louis. It follows the river bottoms from Keytesville, in Chariton county, about 40 miles east of the Richmond sheet, to Kansas City.

The St. Joseph branch of the Santa Fe runs from the bank of the Missouri river opposite Lexington, 8 miles south of Richmond, northwestward through Richmond to St. Joseph, Missouri. From the Missouri river bottoms it runs northward up a small creek to Richmond. There it turns abrutly westward about 2 miles to avoid an outlying mass of the Lathrop plain then turns northward between it and the main mass farther west, crosses the west branch of Crooked river and climbs to the top by way of a small creek from the north. It then follows the plain nearly to St. Joseph.

These roads are all single track.

TOWNS.

The towns and villages located within the area before the construction of any railroad across or near it are Richmond, Morton, Russellville, Millville and Taitsville. None of these are located on the Missouri river bottoms and none of them were close enough to the river to be shipping points. Except-

ing Richmond none of them ever became more than small local retail trading points. They illustrate the fate of towns which without municipal support were compelled to compete with "river towns."

Richmond owes its importance to the fact that it became the county seat of the county and was thereby able to compete with Camden only five miles away, a river town.

It was only a small, unimportant village when the county seat was located there. Its selection was due to the difference between the topography and therefore soil along the river bluffs in the eastern and western parts of the county.

The eastern part of the county is moderately rolling with the loess making a rich soil, was pretty well timbered and therefore early occupied by an agricultural population.

The western part of the county extending from Richmond westward is rather rugged; the breaks of the plateau commencing a little west of Richmond. The valleys are rich, but the higher lands on the plateau were largely prairie originally and since it was not covered with loess was not so fertile. It was not so thickly settled for that reason. When it came therefore to a vote for locating the county seat Richmond was the favorite of the eastern part of the county where the population was thickest, and was the winner. By this means it was able to hold its own against more favorably located towns until steamboating declined and a railroad was built through it. It thenceforward had the advantage.

It is now the shipping and trading point for the population of a large territory of fertile and well cultivated land. It has also become an important mining town and its mining industries are becoming more and more important.

It contains one steam flouring mill with a daily capacity of 125 barrels, two small foundaries, two small wagon and carriage factories and a number of retail stores.

Millville was a few years ago a retail trading point doing a considerable business, but the construction of the Chicago, Milwaukee and St. Paul railway through the southern part of Caldwell county has diverted most of its former trade to the

new towns along the railway. It is situated in the midst of a very good agricultural district, the valley of Crooked river being especially rich. It contains a small water-power flouring mill and three or four small general stores.

Taitsville is another village which has lost its former prosperity on account of the construction of the Chicago, Milwaukee and St. Paul railway.

It formerly contained a flouring mill of considerable local importance and was a trading and milling point for a large territory.

The mill has been removed to Cowgill and the trade has followed.

Fox or Russellville is a country village and post office, containing a small general store, a black-smithing shop and a drug store.

Morton is another village which has suffered on account of competition with a new railroad town. Before the construction of the railroads through the bottoms south of it and the building of Hardin it commanded an important retail trade. Since then its trade has been entirely diverted to Hardin. It is now merely a country post office.

Hardin is the only railroad town within the area. It is the only town within the area located within the Missouri river bottoms. All the old towns were located on the uplands.

Hardin's location is due entirely to the location of the railroads which have fostered its growth. It is the shipping and trading point for most of the area of the sheet east of Crooked river and south of township 54.

The population of the towns and villages are:

Richmond, about	3,210
Hardin, about	800
Millville, about	100
Taitsville, about	50

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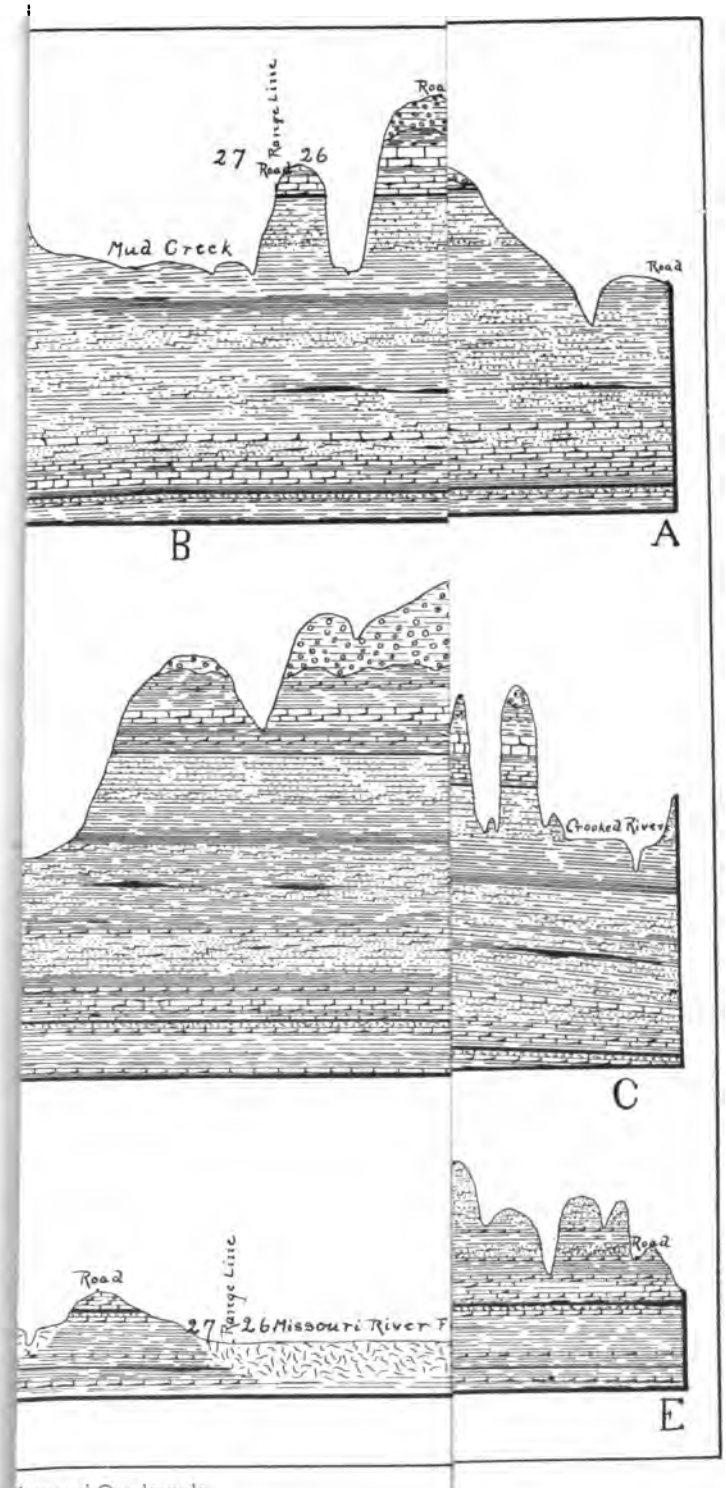

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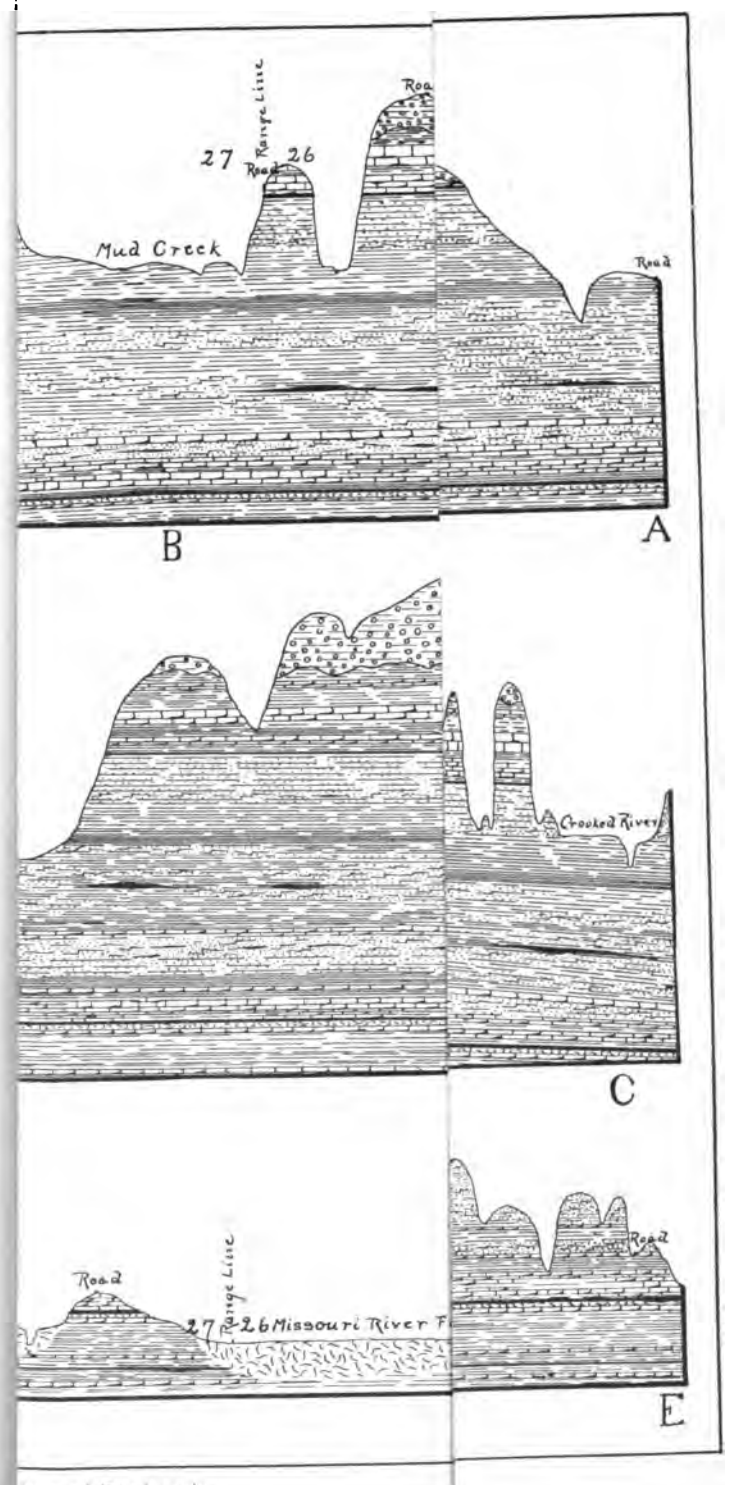

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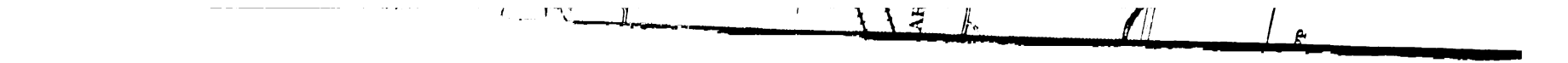

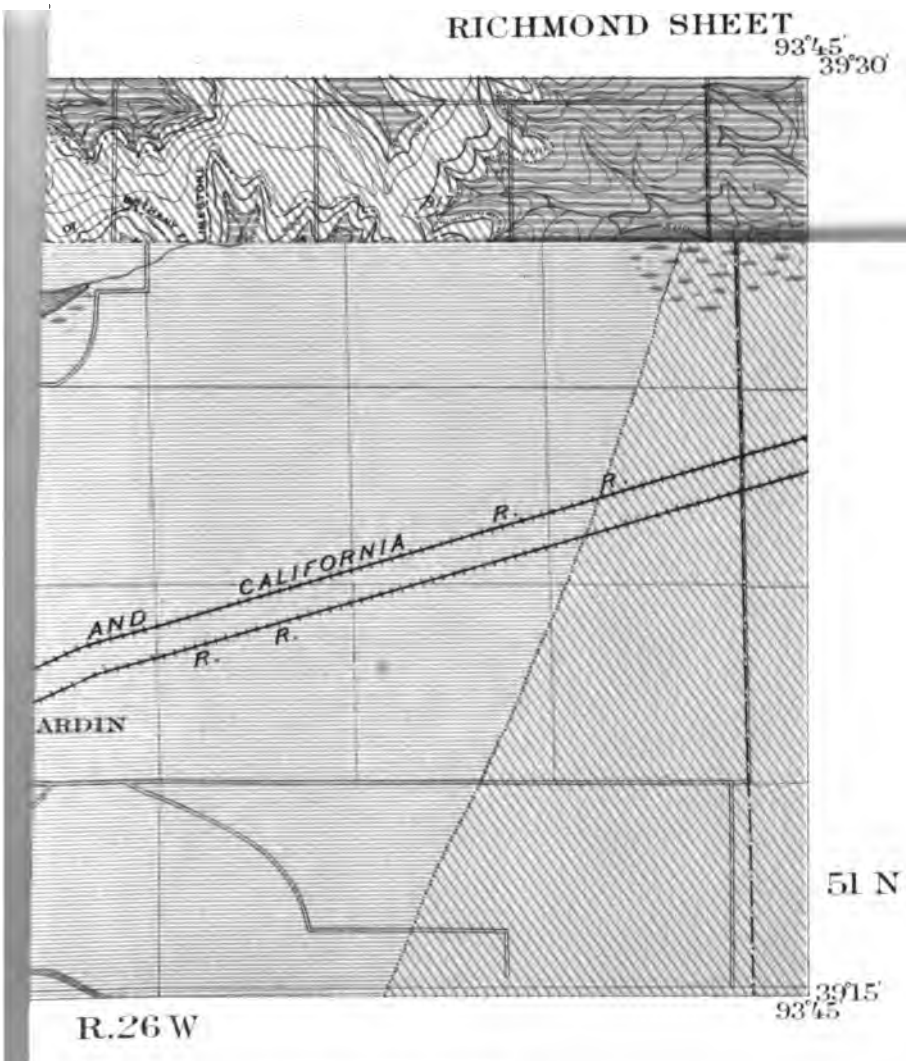

CONVENTIONAL MARKS

⊓ Shaft	— Geological Boundary	S.H. School House
• D.H. Churn Drill Hole	▫ Building	Sh Shale
L.S. Limestone	Ch Church	S.S. Sandstone

MISSOURI GEOLOGICAL SURVEY.

CHARLES R. KEYES, State Geologist.

SHEET REPORT NO. 10.

GEOLOGY OF THE

HUNTSVILLE QUADRANGLE,

INCLUDING PORTIONS OF

RANDOLPH, HOWARD AND CHARITON COUNTIES

BY

CURTIS FLETCHER MARBUT.

PUBLISHED BY

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1898.

G—21

GEOLOGY OF THE HUNTSVILLE QUADRANGLE.

BY CURTIS FLETCHER MARBUT.

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INTRODUCTION.

AREA AND LOCATION.

The Huntsville quadrangle* includes part of the area of three counties: Randolph, Howard and Chariton. It is named from the town of Huntsville, the county seat of Randolph county, and the largest town within the district. It is a quadrilaterial of 15′ extent in latitude and longitude, embracing an area of 230.86 square miles. It is included between the lines 39° 15′ and 39° 30′ north latitude and 92° 30′ and 92° 45′ longitude west of Greenwich. Its position is a little northeast of the center of the state. The eastern boundary of the area is near the mid-line of Randolph county; the northern boundary is about seven miles south of the northern boundary of the county; the southeastern corner extends a little more than a mile into Howard county, and the southwestern corner is about six miles south of the point where the Howard-Randolph line crosses the western boundary of the sheet. This western limit is about three miles west of the eastern line of Chariton county. The location with reference to the county lines is shown in the following diagram:

Figure 30. Showing the relation of the Huntsville Quadrangle to the county boundaries.

* Propposed by the Director of the U. S. Geological Survey and adopted by the Missouri Survey.

PREVIOUS WORK WITHIN THE AREA.

The geology of the Huntsville quadrangle was known in a general way before the present work was begun. During the progress of Swallow's work, Randolph county does not seem to have been visited, or at least no report was published covering it. In the first and second annual reports, issued in 1855,* he states that the sandstone which he placed at the top of the lower Coal Measure series occurs in Howard county and also that certain beds of coal occur there though no sections are described nor localities cited.

In the first report of the Broadhead survey, which included the unpublished fragments of the Swallow survey and the results of the work done during the interval from 1855 to 1871,† there was included a small report on Randolph county signed by Broadhead. In this a general section of the rocks of the county was given. Sections on Moniteau, Sweet Spring and Sugar creeks were described and published. It is not stated at what localities the measurements and observations were made, but the section on Sweet Spring creek does not include the rocks occurring on both sides of the stream due south of Huntsville, so probably the observations did not extend into the area of the Huntsville quadrangle. With the exception of slight differences in the thickness of certain numbers, the sections do not differ from those recently measured in the same localities excepting in the details of the description of individual beds. The occurrence of the Lower Carboniferous rocks was noted in two places within the district covered. Outcrops of several feet each at seven localities in all, were described within the sheet area, some of which are mentioned in this report; and also the occurrence of a great number of exposures of coal beds.

In the report including field work of 1873-74 the Geology of Howard county is considered by Broadhead and Norwood.‡ The latter author examined that part of the county lying within

*Missouri Geol. Sur., 1st and 2nd Ann. Reports, p. 87, 1855.
†Missouri Geol. Sur., 1855-71, pp. 93-110.
‡Missouri Geol. Sur., 1873-74, pp. 178-221, 1874.

the area of the Huntsville quadrangle. The local sections measured and described by him in this part of the county are about the same as lately observed but that part of his general section which embraces rocks occurring within the quadrangle differs from the one complied from recent observations; especially is this true regarding the thickness of the rocks between the Summit and Bevier coal beds. An interval made up of sandstones, shales, limestone and coals, amounting to about 163 feet was reported, while in reality where the two extreme beds in question are exposed in the same hill and where there are numerous shafts and drill holes which penetrate both coals, the records show that the interval within the greater part of the area of the quadrangle is only about fifty feet. Norwood's coals B and E correspond to the Summit and Bevier coals, respectively, of this report. This discrepancy is probably due partly to a thickening of the interval between the coals southwestward where Norwood's measurements were made and partly to a duplication by him in making up his general section. He described a section on Doxy's Fork, from Roanoke westward with which recent observations agree excepting in the amount of detail. A section measured by Norwood about two miles northwest of Armstrong (Tp. 52 N., R. XVI., Sec. 20, Nw. qr., S. ½), agrees in the main with the new section measured near the same place. The coal C in the former section is correlated with the Macon City coal.

PHYSIOGRAPHY.

TOPOGRAPHY.

The Huntsville quadrangle lies just on the western side of a broad flat area constituting the water shed between the Missouri and Mississippi rivers and locally called the "Grand divide." It has been described by McGee as "simply a broad and remarkably smooth and level plain, scalloped and ravined by secondary drainage along its margins but imperfectly drained interiorly." Its axis extends north and south a few miles east of the eastern boundary of the sheet and small parts of it extend into the area, bounded on three sides by the sharply

cut valleys of this part of the district. Its height is remarkably uniform. At Higbee it is about 875 feet above tide level. At Moberly only a few miles east of the northeastern part of the sheet it is about 870 feet; and northward through Excello, Jacksonville, Macon and Glenwood it rises very gradually and at the Missouri–Iowa line is about 950 feet above tide level. Topographically the area of the quadrangle is a broad, even plain, lying about 200 feet above grade and wholly within the area of the Warrensburg platform.* With the exception of the southeastern corner, it is now thoroughly dissected. The larger streams have developed broad floodplains, bordered by low gently sloping bluffs. The western part of the district is nearly graded. The eastern border is still in a youthful stage.

The Features. For purposes of description the features of the area may be divided into three divisions: (1) Small areas of the upland plain, the "Grand divide," so-called; (2) the "crenulated margin" of the "Grand divide," and (3) the undulating upland of the northwestern part of the area, including the wide floodplains of the larger streams. The first division consists of the flat uplands of the southeastern part of the sheet, which are noticeable in the vicinity of Higbee and a few miles north of it. They run westward between the narrow valleys of the larger streams. The upland belts followed by the Chicago and Alton railroad from Higbee to Armstrong, and by the Wabash railroad from Huntsville to Moberly, six miles to the east, are long, rather narrow, parts of this upland, which extend further westward than any other part of the upland within the limits of the quadrangle. From these areas of flat upland the transition to the next division, the "crenulated margin" of the "Grand divide" is abrupt. This belt enters the district at the northeastern corner, and constitutes the rough Sugar creek country. Passing southward, its western margin includes the town of Huntsville, with its steep, narrow ravines and the thoroughly incised areas around Sweet Spring and Silver creeks. From the head of the latter it turns westward along the northern side of the Higbee-Roanoke extension

*Phys. Feat. of Mo. Mo. Geol. Sur., Report, Vol. X. p. 68.

of the upland, southward and back eastward on the southern side of the upland, extending east through southern Randolph and northern Howard counties into Boone county. It is the most clearly marked physical and cultural belt of the area. Everywhere, excepting at the western terminus of the upland, in the vicinity of Roanoke, it is covered by a dense growth of small white oak saplings. Its soil is a yellow, sticky clay. The narrow roads wind through the thickets following the labyrinthine ridges. The third division includes the northwestern part of the sheet, and consists of the wide floodplains of the larger streams, the undulating uplands bordering them and the narrow, though quite even crested ridges, separating the drainage areas of the streams; in short, all the more subdued relief of this part of the district with its undulating profile, as distinguished from the second division with its angular, almost rectangular profile, and the wide, flat plain of the first division. The ridges of this part of the area are not so high as the "Grand divide," though the differences of elevation are not more than fifty or sixty feet. Their crest lines are nearly as even but they are narrow. Their original height has probably been somewhat reduced by the present drainage; the narrow crests allowing the gradual wearing down of the clays from the top without a notching by the approach of streams from opposite sides.

Age. As a whole the topography is adolescent. There are some features of extremely youthful aspect and others of a decidedly mature appearance. The narrow, sharp incision of the western edge of the grand divide is extremely youthful in character, but in marked contrast to this are the wide floodplains of the larger streams of the area with a typically mature topography. It is an area of extremely wide topographic variations. The association of wide floodplains along rather small streams with wide stretches of undissected uplands all within a small area is not, however, an uncommon occurrence in the northern part of Missouri.

Position in the topography of northern Missouri. There are two noticeable features which characterize the topography

of the area, in common with a considerable part of northern Missouri. The first feature is the great width of the floodplains compared to the size of the streams now flowing in them. The extreme width and the shallowness of the valleys serve to render them inconspicuous features, or rather, conspicuous because of their lack of prominent features. Where the features are most characteristic the upland is but little more than a hundred feet above the floodplains of the streams. The latter, even when so small that they almost wholly disappear during the summer have floodplains from one to four or five miles in width. The valley slopes are rounded and without rock exposures.

Along with this extremely faint relief is a remarkable parallelism of the drainage. The streams all have almost due southward courses. Small streams persist in this courses for many miles running parallel to a large stream and in many cases separated from the larger ones by a strip of upland less than a mile in width. Puzzle creek, a very small stream in Macon county, parallels Chariton river, the largest stream in northeastern Missouri, for a distance of 12 or 15 miles, and the average width of upland between the two valleys is but little more than two miles. The same relation exists between Middle Fork of Chariton river and Morrow creek, East Fork and Muncas and Dark creeks and in many other cases in certain parts of northern Missouri. Another noticeable fact is that these two characters, faintness of relief and parallelism of streams, accompany each other. Where one is prominent the other is equally so. On the basis of the presence or absence of these characteristics the drainage of northern Missouri falls into four north and south belts. The first belt extends from the Mississippi river westward to the Missouri-Mississippi watershed, the width being about 50 miles. It is characterized by a southeastwardly flowing drainage with an approach to parallelism of streams though not reaching the almost geometrical parallelism of the next belt. The streams flow in deeper valleys with steeper slopes and narrower floodplains than those of the Huntsville quadrangle.

The next belt extends from the Missouri-Mississippi watershed westward to the Bethany escarpment in Mercer, Grundy and Livingston counties. It is within this belt that the Huntsville quadrangle lies. Here the features described above, the parallelism of streams and faintness of relief reaches its highest development.

The succeeding belt extends from the Bethany escarpment westward to the eastern border of Nodaway, Andrew, Buchanan and Platte counties. In this also the general direction of drainage is southward and the large streams are more or less parallel to each other but the drainage basins are wider and the small streams have a more widely branching arrangement than those of the belt bordering this to the eastward. The valleys are deeper, the floodplains narrower and the slopes steeper than the latter belt also. This belt is more like the first belt described than the second.

The next belt extends over the northwestern corner of the state. It approaches the second belt very closely both in parallelism of streams and depth, width and side slopes of the valleys.

The first and third and second and fourth belts therefore approach each other in character.

When these belts are examined with respect to the physiograpic belts* of the state a very important relation is at once discovered.

The belts of parallel drainage and wide, flat bottomed streams occupy the lowlands while the belts having deeper, narrower valleys and less parallelism of drainage occupy the uplands. The wide, flat bottomed shallow valleys occur in the lowland belts as we should expect, but there is no evident reason at first sight why these should be characterized by a more complete parallelism of drainage than the other belts. The rocks here are all soft and lie nearly horizontal so that it cannot be due to adjustment to geologic structure; so that their present courses must be essentially the same as conse-

*Physical Features of Missouri. Mo. Geol. Sur., Vol. X, Platte II and pp. 50-73, 1896

quent courses of these streams. It must be due therefore to the constructional features of the region over which the streams began their work. McGee* has stated that such a condition is the result of consequent drainage over a featureless plain sloping gently southward. The drainage of the upland belts is consequent also but it lacks the features of that of the lowland belts. The constructional surface of the uplands must have been different from that of the lowlands. Another significant matter is the fact that the extreme simplicity of constructional surface necessary to produce the drainage of the lowlands can be produced only by constructional processes, by deposition of material from water. This process could not have acted on the present lowland belts alone until after the lowlands existed as such. A previous drainage system on the lowlands must have worn them out and reduced them almost or wholly to a peneplain. This peneplain must then have been evenly coated with another deposit which obliterated the former drainage lines and produced a featureless plain over which the present drainage started.

Manifestly we are in this case limited to glacial processes for the production of this plain. Some confirmation of this conclusion is found in the great thickness of drift clays which are spread over the region. This brings us also to the recognition of the post-glacial age of these valleys. This is a matter that must find confirmation on the ground before it is accepted as a fact. There are many indications in this region, however, aside from what has been said above, that these valleys are post-glacial. Field study in the neighborhood of Columbia is nearly conclusive as to the post-glacial age of the valleys here.

The great width of these valleys is the product therefore of post-glacial erosion in soft rocks in an even plain, but little above the grade of the stream draining it. In this view of the case the valleys are not abnormally wide.

The Huntsville quadrangle includes parts of two of the belts described above. The eastern and southeastern part is

*Transactions St. Louis Academy of Science, Vol. V, p. 310.

characterized by the type of drainage represented in the first belt, dentritic arrangement of streams and narrow valleys. The northwestern part reaches into the area of wide-bottomed valleys and parrallel streams.

The distribution of the zones of altitude is shown in figure 31.

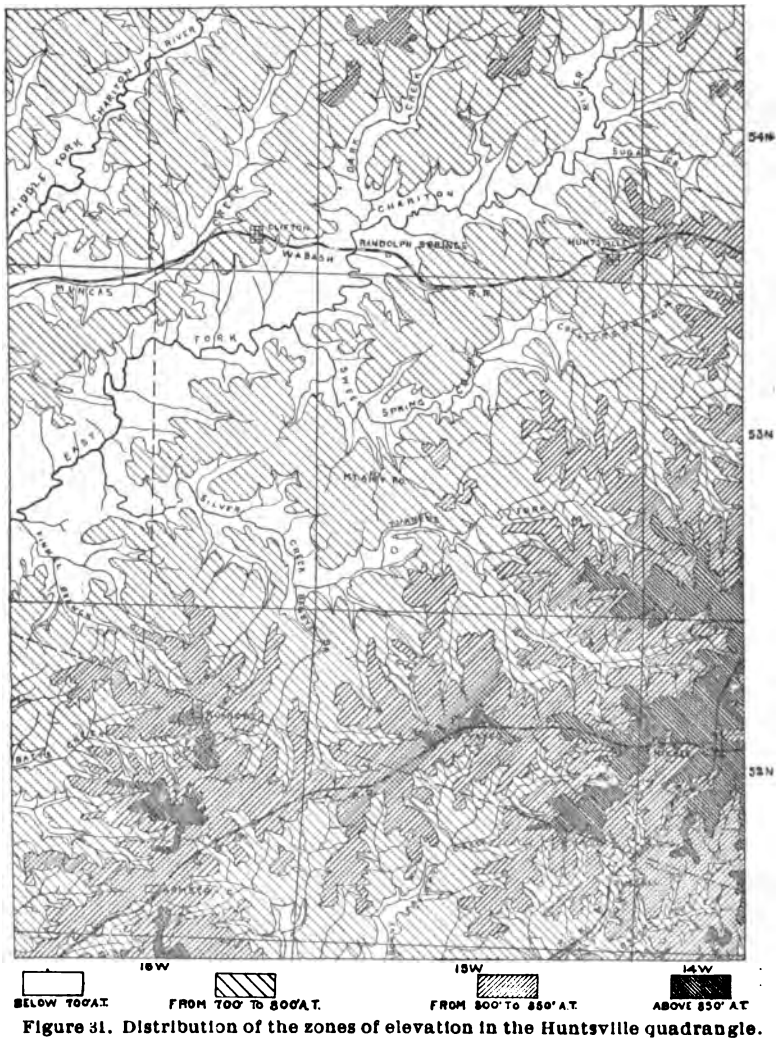

Figure 31. Distribution of the zones of elevation in the Huntsville quadrangle.

HYDROGRAPHY.

The entire area covered by the Huntsville quadrangle is in the drainage basin of the Missouri river, that part south of the Chicago and Alton railroad entering that stream directly, while the rest is drained into the Chariton river. The streams are all small; the minor ones becoming dry during part of the year, and during a protracted drouth the largest become almost so.

East Fork of Chariton river is the largest stream traversing the area. It rises in Adair county and flows almost due southward for about forty-five miles until it reaches the northern part of the Huntsville quadrangle. It then changes to a southwesterly course. It flows into the Chariton river a few miles above the mouth of the latter. It has a fall of about three feet per mile within the area of the quadrangle.

Middle Fork of the Chariton river is the next in size. It rises in the northern part of Macon county, about thirty-five miles north of the northern part of the area, and flows about parallel to the East Fork. Its average fall per mile is about the same as that of the latter stream.

Sweet Spring creek is third in size. It rises near Moberly, about four miles to the northeast of where it enters the sheet, and flows in a westerly direction across the area. It, as well as the East and Middle forks, flows in a deep channel in the floodplain, with muddy banks and bottom. The channel is extremely sluggish, excepting during high water stages, and the water is always dark and turbid.

Silver creek, near the middle of the sheet, is a little smaller than Sweet Spring creek. It has a greater fall per mile, its channel is not so deep, its floodplain not so wide, and its water not so muddy as the streams just named. Its channel is filled with sandstone instead of mud.

Besides the four water courses mentioned there are other streams which are smaller. They are shown on the map and need no further mention in this connection.

FORESTRY.

Very nearly the whole of the area occupied by the Hunts-

ville sheet was originally covered with forest trees. Probably the flat top of the "Grand divide" and the older part of the flood plains of the larger streams were the only areas bare of timber growth at the time the country was settled. The principal forest trees now occurring within the area are the white oak (quercus alba), laurel oak (Q. imbricaria), pin oak (Q. palustris), post oak (Q. rubra), black oak (Q. tinctora), swamp white oak (Q. bicolor), birch (Betula nigra), American elm (Ulmus americana), slippery elm (U. fulva), sycamore (Platanus occidentalis), cottonwood (Populus monilifera), mulberry (Morus rubra), black walnut (Juglans nigra), shellbark hickory (Carya alba), pignut hickory (C. procina), butternut hickory (C. amara), ash (Fraxinus sambucifolia), white maple (Acer dasycarpum), sugar maple (A. saccharinum), hackberry (celtis occidentalis) linden (Tilia americana) wild cherry (Prunus serotina) and locust (Gleditschia Tricanthus).

Of shrubs and smaller trees there are: the buckeye, horse chestnut, black haw, several species of thorn, red-bud, pawpaw, iron wood, dogwood and crab-apple.

In the eastern part of the sheet along the margin of the "Grand divide," especially around the head branches of Bonne Terre, Silver, Sweet Spring and Sugar creeks, the growth is principally white oak. A few black and red oaks grow in the sandier portions and a few elms and cottonwoods in the hollows. The trees are for the most part too small for lumber. On the rocky hillsides of the tributaries of Bonne Femme and Silver creeks, and those flowing westward from the southern part of the quadrangle, the growth is principally red oak, chestnut oak, black walnut, white oak and pin oak, with the two first named predominating. In the vicinity of Roanoke and Armstrong, on the rich uplands the growth is elm and black walnut, with scattering members of a large number of other species. In the flat floodplains of the larger streams the growth is principally laurel oak, with elm in the better drained portions and white maple on the banks of the streams in the recently formed alluvium. North and west of the east fork of Chariton river the growth is elm, laurel and red oak,

shell-bark hickory, walnut and white oak, the greater part being hickory, elm and laurel oak. White oak grows in the lands along the eastern side of the middle fork of the same river.

The timber of the area which was of value for lumber, as an article of commerce, has long since been removed. There is enough standing to supply a decreasing local demand, but the quality is poor. There is some walnut timber, yet standing, in the vicinity of Armstrong. Large quantities of walnut logs were shipped from this place a few years ago. The large timber has all been cut out. Pine lumber is coming more and more into use as a building material; indeed it may be said that, with the exception of brick, it is the only building material now used; the farm lands are fenced in with wire, and cheap coal makes wood valueless for fuel, so there is at present very little demand for what timber remains.

GEOLOGY.

The formations represented in the area of the Huntsville sheet are the indurated clastic rocks and incoherent superficial deposits. They belong to the Paleozoic and Cenozoic eras of geological time.

The Paleozoic rocks belong to the Carboniferous period, and are subdivided into the Lower Carboniferous or Mississippian series and the Coal Measures. Of the latter series only the lower or Des Moines stage is represented. The deposits of the Cenozoic era belong to Pleistocene time and include glacial drift, loess and alluvium.

The general relations of formations occurring within the area are shown in the following table:

TABLE OF GEOLOGICAL FORMATIONS.

	Recent.		Alluvium.
Cenozoic.	Pleistocene.	Drift.	Loess, Gray Loamy Clay.
			Till.
Palæozoic.	Pennsylvanian.	The Moberly Sandstone.	Middle Coal Measures.
		Des Moines.	Lower Coal Measures.
	Mississippian.	Augusta.	Burlington.

GENERAL SECTION.

The general section of the rocks of the area is shown in the accompanying diagram (figure 32). It must be borne in mind concerning it, that it is subject to the same limitations as other general sections. No such section can show all of the stratigraphic details of a large area. The succession is apt to vary even within small areas. New strata often appear coming in like a wedge between adjacent beds. Others pass into a different kind of deposit while the thickness changes constantly. This is especially true in an area such as the one under consideration, where there are two or more series of beds, each series separates from the adjacent ones by unconformities. The upper surface of each series is therefore more or less uneven as a consequence. The

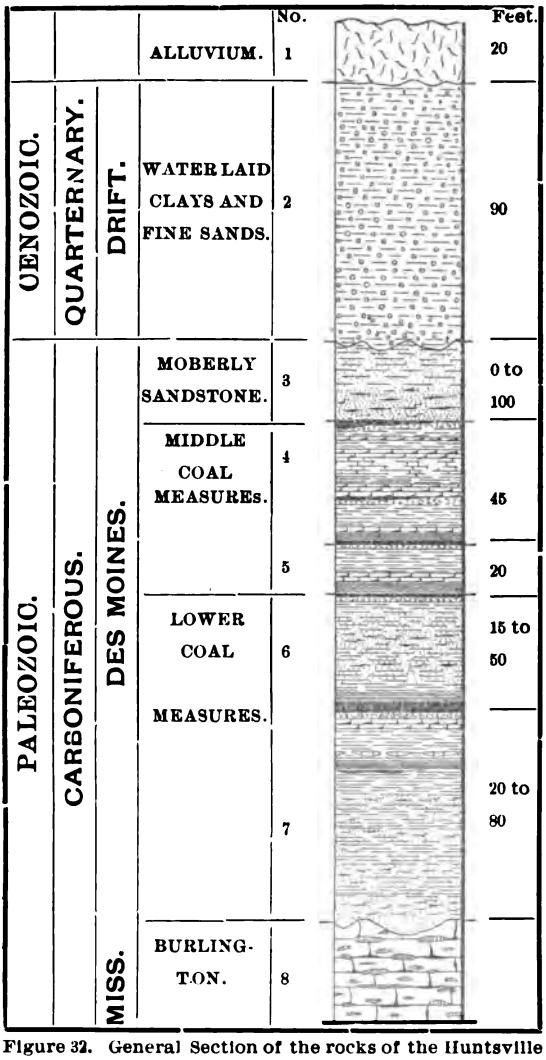

Figure 32. General Section of the rocks of the Huntsville quadrangle.

overlying deposits are thicker in the depressions and, on account of varying conditions prevailing because of this irregular surface and consequent irregular depth of water, they are of different character in adjacent areas. As the depressions became filled up producing a more even surface on which deposition took place, more uniform conditions prevailed. The rocks deposited under such conditions therefore are more persistent in both thickness and character. This stage was reached in the area of the Huntsville sheet a short time before the deposition of the Bevier coal bed. The accompanying general section therefore may be more relied upon above the base of the Bevier coal bed and its underlying limestone than below it. That part of the general section from the Bevier coal bed upward is an average of the conditions shown in the several shafts in the eastern part of the quadrangle. The lower end of the section is compiled from a number of exposures on Sugar creek northeast of Huntsville.

GEOLOGICAL FORMATIONS.

LOWER CARBONIFEROUS ROCKS.

The Lower Carboniferous rocks are exposed in only two places within the area. They consist of subcrystalline, gray and bluish gray limestones, containing nodules and interstratified beds of chert. They are in all probability a part of the Augusta division, but no fossils have yet been discovered which make this correlation certain. One of the localities referred to is at the old millsite on the bank of Chariton river (Tp. 54 N., R. 15, Sec. 12, Se. Sw. ¼). This place was visited by Broadhead, and the rocks were correlated by him with the Archimedes (Keokuk) limestone. He says "the upper portion is a three-foot bed of chert, and next below are beds of gray limestone, interstratified with chert." The same locality was visited in 1890 by Gordon, who states that "The bank of the river is covered with chert and limestone fragments, apparently due to the decomposition, in situ, of a bed of (cherty) limestone. The limestone is coarse, subcrystalline, and is filled

with fossils in a fragmentary condition." The other locality referred to is at the Bagby mill, on Sweet Spring creek, in Tp. 53 N., R. XV W., Sec. 17. This place also was visited and described by Broadhead.* He says "There are about twenty feet of coarse, gray limestone interstratified with chert. The fossils contained are bryozoans, Cyathophyllum and Productus punctatus, supposed to be equivalent to Professor Hall's Keokuk limestone." Gordon says of the same outcrop that "The total thickness exposed is about thirty feet. The strata are thin (three to twenty inches), with very thin or no shale partings, with a layer of somewhat finer and whiter material than the rest near the middle of the exposure. Broken fossils are numerous. Chert is plentifully distributed, usually in nodular masses, though sometimes in layers." The accompanying diagram shows its relations to the surrounding rocks.

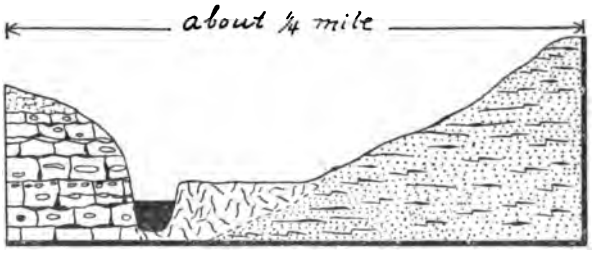

Figure 33. Cross section at Bagby's mill.

The Lower Carboniferous rocks were struck in the Hammett drill hole but no details were obtained from the record. It shows sixty-seven feet of sandstone and shale below the Bevier coal bed which are presumably Coal Measure rocks. Beneath this, fifteen feet of limestone was encountered and underlying that four feet of sandstone. The drillers reported the rest of the section "granite." This, without doubt, is the hard, cherty limestone beds of the Lower Carboniferous. The top of this formation is placed at the top of the fifteen-foot limestone for the reason that no bed of Coal Measure limestone is known so near the base of the coal bearing rocks. The top of the Lower Carboniferous formation here is therefore, about

*Missouri Geol. Sur., 1855-71, p. 100. 1872.

640 feet above tide. At the outcrop of this formation at the Bagby mill the top is about 700 feet above sea-level, thus making within a distance of two miles a difference of elevation between the top of the formation at the two places of about 60 feet. The line of juncture between the Lower Carboniferous rocks and the overlying Lower Coal Measure rocks is an unconformable one. The Lower Carboniferous rocks were subjected to erosion for a long time before the deposition of the coal bearing strata. The uneven surface of the former is shown in the two places where they come to the surface and also in the relative difference in elevation of the upper surface of the formation as shown by the Hammett drill hole and the outcrops. At the latter they lie horizontally, so also do the overlying Coal Measure rocks. The inequalities of surface are not due to folding nor is there any evidence whatever of faulting. The further fact that there is an abrupt change from limestone to sandstone in passing from the Lower Carboniferous to the Coal Measure rocks, from an open sea formation to a shore deposit seems sufficient evidence for that conclusion.

COAL MEASURES.

LOWER COAL MEASURES.

(Des Moines Formation.)

The Lower Coal Measure rocks are exposed over only a small part of the area of the Huntsville quadrangle, they are confined to the low lying portion along the streams. In the eastern part of the sheet they are mostly below the 740-foot contour; in the western part they are below the 680-foot contour. The total superficial area within which these rocks come to the surface is not more than thirty square miles.

The line of delimination between the Lower and Middle Coal Measures is placed at the bottom of the clay underlying the Macon City coal bed which varies in position from fifteen to thirty feet above the Bevier coal bed.

The maximum thickness of the formation exposed at the surface is not more than fifty feet and the maximum thickness penetrated at any point is not more than 120 feet. The thick-

ness is irregular as indicated by the irregularity of the base of the formation, varying from about thirty-five feet as a minimum to an unknown thickness, though probably not more than 150 feet as a maximum.

The rocks of the Lower Coal Measures consist of sandstones, shales, clays, limestones and coals. The first two greatly predominate. In Tp. 54 N., R. XV, W., Sec. 12, Se. qr., Sw. ¼ there is, according to Broadhead, a sandstone about twelve feet thick. It is highly impregnated with iron oxide and is correlated by him with the Ferruginous sandstone of Shumard. It has, however, been shown by Nason* that the impregnation is only local. No fossils have been reported from this division. It was apparently placed there on lithologic grounds. Since these colorations have been shown to be local it seems highly probable that it is the representative of the bed of sandstone and shale below the Bevier coal in the Hammet drill hole. It is thinner but it lies on the top of an elevation of the Lower Carboniferous land. It would naturally be expected to be thicker in a depression of the old surface. If that be true it is unconformable on the Lower Carboniferous rocks. There is no indication of any unconformity between this and the overlying beds. The placing of it therefore in the Coal Measures seems justifiable. The fact that the top of the Lower Carboniferous rocks at their outcrops is so near the horizon of the Bevier coal bed leads to the conclusion that most of the Coal Measure rocks below that horizon consist of small channel and basin deposits generally of sandy or shaly material, but of greatly varying thicknesses. It is not impossible that they contain small basins of coal and even of limestone. These basins had become pretty evenly filled up some time before the deposition of the Bevier coal bed and its associated rocks. The rocks in Section IV, p. 335, lie below this coal bed and have been traced over a large area. In Macon county they are associated with a bed of coal. Broadhead reports it with them in Randolph county but it was not seen in the area of the quadrangle. It probably extends into the

* Missouri Geol. Sur., Rept. on Iron Ores, p. 182, 1892.

northern part of the county, even if it does not reach the northern part of the quadrangle. It is not reported in the Hammet drill hole, though a limestone is reported at about this horizon.

Near shore conditions continued to prevail for some time, but before the Bevier coal bed was deposited open-sea conditions prevailed long enough for the deposition of the limestone bed underlying it. It persists in character and thickness over the greater part if not over the whole of the area, and has been traced over a great extent of adjacent territory. Then came the formation of the Bevier coal bed. It persists over a considerable district both in the area of the quadrangle and beyond it. The great swamp extended parallel to the shore for many miles. It marks a rise of the area from the comparatively deepwater conditions which prevailed during the deposition of its underlying limestone. It was terminated abruptly by some change in conditions which inaugurated the deposition of the overlying shales. The change was so sudden that the transition in most localities from coal to non-bituminous shale is sharp, and uniform conditions prevailed over the area during the deposition of the thick bed of sandstone and shales which overlies the coal and extends upward to the base of the Middle Coal Measures.

Within the area of the quadrangle the Bevier coal bed is generally overlain by a light colored micaceous shale but in many parts of Macon county and in the northern part of Randolph county a sandstone overlies it, though in this case the transition from coal to sandstone is as sharp as that from coal to shale further southwest.

The upper line of delimitation here used for the Lower Coal Measures is the one adopted in this region by the present survey. It is the result of an attempt to carry the line adopted in Lafayette county and described in the Higginsville sheet, eastward parallel with the strata, into the area of the Huntsville sheet. It is the same as the line adopted by Gordon in his report on the Bevier sheet which joins the Huntsville sheet on the north. For the sake of uniformity it is considered

best to adopt it for this area also. The line was adopted in Lafayette county in an attempt to make a division between the deposits which were laid down near the shore, sands, shales and coals, and the more open sea deposits in which limestone is a conspicuous constituent. When carried into the area of the Huntsville sheet it still serves the same purpose reasonably well. The rocks below it are almost wholly made up of sandy and shaly deposits, only one persistent bed of limestone occurring among them—that beneath the Bevier coal bed, while above this line limestone forms a rather important proportion of the rock.

THE MIDDLE COAL MEASURES.

(Des Moines Formation.)

The rocks of the Middle Coal Measures are exposed over the greater part of the area of the sheet. They underly the surface of all the upland area excepting that underlain by the Moberly sandstone.

The upper line of delimitation of the formation is not reached in the area of the sheet. The total superficial area over which these rocks are exposed is about 165 square miles. The rocks are limestones and sandstones, clays and coals. The first two named are represented in about equal proportions. Sandy shales are not abundant and sandstones even of less importance. Two persistent beds of coal, both of them thin, and two others which are of local importance only, are found within the area of the sheet. Clays are unimportant as factors in making up the rock section of the area. They are confined to thin beds underlying the coal beds.

The shales are generally argillaceous and of a drab color. On exposure they often decompose readily into a mass of stiff clay. In contact with coal beds they usually become bituminous and fissile.

The limestones occur in strata ranging from one to fifteen feet in thickness; are generally of a very fine, compact texture, and occur in massive or thin beds of light drab, bluish and buff colors. They vary slightly in composition. All are more or less impure and many contain a rather large proportion of

organic matter. There is very little tendency to a crystalline structure. They are generally more resistant to erosion than any of the other rocks of the area, though they yield to solution quite readily. They are conspicuous in the steep bluffs along the creeks. They contain fossils but not generally in a good state of preservation. These rocks, like the upper beds of the Lower Coal Measures, persist over a large area, including that of the Huntsville quadrangle. They have been traced northward as much as twenty miles north of the area and probably continue further. Westward their persistence is not so clearly established. There are certain beds of limestone which agree in character with these but the associated rocks do not agree so well. In a shaft recently sunk at Salisbury in Chariton county, no beds whatever that could be indentified with any within the area of the sheet were encountered. There is a considerable development of sandstone in this direction the relations of which are not at all clear. It seems certain that parallel to the old shore line as it existed during this part of Carboniferous time, these rocks are persistent for a considerable distance, but at right angles with the shore line their persistence is doubtful, at least very far beyond the limits of the sheet, though it will be clearly shown that they extend to its western limits.

THE MOBERERLY SANDSTONE.

Under this head is placed a deposit of an unknown thickness of sandstones, shales and conglomerates, which extends from east to west across the middle of the quadrangle in a belt about two and one-half miles wide.

It contains coal measure plants and a few thin coal beds of small area, but its age relative to the other coal measure strata of the state is not known, excepting that it is younger than any of these strata in the area of the quadrangle. It lies upon these unconformably and has a basal conglomerate made up of water-worn fragments of limestone and shale. It has been traced eastward into Monroe county, but westward it has not been followed with certainty, on account of the difficulty of distinguishing it from certain other sandstone beds, which ap-

parently are the regular conformable members of the coal measure series. Its great length compared to its width leads to the conclusion that it represents a channel of erosion formed during a temporary uplift during the Coal Measure period which on submergence became filled with sandy and shaly material. It probably belongs to an extensive drainage system of that time, and is probably connected with the Warrensburg sandstone of Johnson, Lafayette, Ray and Carroll counties.

It is apparently not the result of one of those minor oscillations of the land and the shore line which occur frequently but which are of small extent and short duration, but represents an extensive uplift, raising a large area above the sea, which remained so long enough for the development of a considerable drainage system.

The regular Coal Measure strata are cut out to an unknown depth and replaced by this sandstone. The Bevier coal bed and all above it have been taken out but the lower beds have not been taken from so wide a belt as the higher ones. The channel sloped gradually downward to its axial line. The lower beds of the regular strata may underly the margins of the sandstone belt for a short distance, the strip of missing strata becoming narrower toward the base of the old valley.

There were doutless many tributaries to the stream which excavated the channel but none have been found which could be traced far enough to prove the connection. A bed of sandstone which bears the same relation to the older rocks of the area as the Moberly sandstone was found about two miles southwest of Yates. It is unconformable on the limestones and shales and has a basal conglomerate made up of fragments of these rocks but the details of its occurrence were not worked out.

SYSTEMATIC DESCRIPTION OF DATA.

For economic and scientific purposes the various outcrops of rocks which were observed within the area will be described. For the Lower Carboniferous rocks no data other than what has already been given is at hand.

In describing the outcrops of the rocks of the district a three-fold division is made describing separately the outcrops of the conformable Coal Measures, the Warrensburg sandstone and the Quarternary deposits. In doing this for the Coal Measure rocks the area will be gone over in systematic order, commencing in the northeastern corner and taking the northern tier of townships running westward to the western side, then returning and taking the next tier in like manner and so to the end.

THE COAL MEASURES.

Outcrops in Townships 54 N, Ranges XIV, XV and XVI W.

In that part of Township 54 N., Range XIV W., which lies within the area of the sheet there are no outcrops which show a great thickness of those rocks at any one place, but the resitant limestone beds may be seen in almost every hillside.

The record of shaft No. 1, three miles east of Huntsville, though it is located east of the area about half a mile, is here introduced to show the general character of the rocks of the Middle Coal Measures here and their relation to the Lower Coal Measures from to the Bevier coal bed to the top.

I. Record of Shaft No 1.

(T. 54 N., R. XIV W., Sec. 33, Se. qr., Nw. ¼.)

Top of shaft is about 820 feet A. T.

		Feet.
1.	Surface, soil and clay	18
2.	Limestone	2
3.	Shale, sandy	10
4.	Sandstone	10
5.	Shale, sandy	12
6.	Limestone, blue	2½
7.	Shale, black, fissile	4
8.	Coal, *(Summit bed)*	½
9.	Clay	1
10.	Limestone, hard	10
11.	Shale, black, fissile	8
12.	Coal	2
13.	Clay, *Top of Lower Coal Measures*	11½
14.	Shale, sandy	15
15.	Coal, *(Bevier bed)*	4
16.	Clay	2

About a mile west of this a shaft was sunk in the summer of 1890 by Mr. J. Breckenridge of Huntsville. The following record was furnished:

II. Record of Breckenridge Shaft.

(Tp. 54 N., R. XIV W., Sec. 32, Nw. qr. Se. ¼.)

Top of shaft is about 820 feet A. T.

		Feet.
1.	Clay	22
2.	Sandstone, brown, friable	½
3.	Shale, soft	10
4.	Limestone	1
5.	Sandsone and shale, soft	50
6.	Limestone (?), nodular	2½
7.	Coal *(Bevier bed)*	3½
8.	Sandstone	6
9.	Coal	1
10.	Clay	1

The coal bed at the top of the Lower Coal Measures is not represented here. The limestone, No. 4, is probably equivalent to the limestone overlying the Summit coal.*

Shaft No. 4 lies just over the range line in Range XV W., but it is so closely related to the sections of the two shafts just given that I shall insert it here. It is situated on the railway a short distance west of the Huntsville station.

III. Record of Shaft No. 4 at Huntsville.

The top of the shaft is about 790 feet above sea level.

		Feet.
1.	Soil and drift	7
2.	Dark streak	⅔
3.	Clay, drab, shaly	1⅓
4.	Clay, yellowish, gypsiferous	6
5.	Shale, drab, calcareous	5
6.	Limestone	3
7.	Shale, argillaceous	2½
8.	Limestone	3
	(Top of Lower Coal Measures).	
9.	Sandstone	4½
10	Shale, drab	29
11.	Coal *(Bevier bed)*	4

*So named in the report on the Bevier Sheet, from the station of that name a few miles west of Macon on the H. & St. J. R. R.

The Macon City coal, it will be noticed, is not present in either of the last two shafts. These sections are different in that respect from those in all other parts of the quadrangle from which this bed has not been removed by erosion.

The rocks below the Bevier coal bed are exposed along Sugar creek and its tributaries northeast of Huntsville. About two miles northeast of town the following outcrop occurs:

IV. Record of Outcrop.

(Tp. 54 N., R. XIV W., Sec. 20 Sw. qr. Ne. ¼.)

Top of outcrop is about 725 feet above sea level.

	Feet.
1. Sandstone..	8
2. Shale, dark	7
3. Shale, sandy, becoming more argillaceous at bottom (exposed).	10

About three quarters of a mile up the creek from this locality there is an exposure of about 18 inches of dark bituminous limestone underlain by about four feet of black, fissile shale. The limestone lies about 65 feet below the top of the Lower Coal Measures. The rocks below and above this exposure were concealed here, but it is reported that about 12 inches of coal lie immediately under the shale. Broadhead* reports a bed of coal in this and Macon county on this horizon. In Tp. 54 N., R. XIV W., Sec. 20, Sw. ¼ of the Sw. ¼, the Bevier coal is exposed in a narrow ravine. The bottom of the bed was not visible. It is overlain by a light colored shale.

In Tp. 54 N., R. XV W., Sec. 11, Nw. qr. Nw. ¼, the same coal bed is exposed about 30 feet below the top of the Lower Coal Measures. The bed is here overlain by a firm reddish sandstone which graduates upward into shale within six or eight feet above the coal. The underlying limestone, about three feet thick, is exposed in the road 390 feet south of the outcrop of coal. Near the middle of the western line of section 23, of the same township and range is the Hammett drill hole. The record is as follows:

*Report Missouri Geol. Survey, 1855-71, p. 003, 1872.

V. *Record of Hammett Drill Hole.*

Top of hole is about 765 feet A. T.

		Feet.
1.	Soil and clay	8
2.	Limestone	1
3.	Clay	7½
4.	Limestone	2¼
5.	Shale	8¼
6.	Limestone	8¼
	This is five feet above the top of the Lower Coal Measures.	
7.	Shale and sandstone	34½
8.	Coal *(Bevier bed)*	3
9.	Shale (probably clay)	2
10.	Limestone	4½
11.	Sandstone	2½
12.	Limestone, bluish gray	½
13.	Shale	2
14.	Limestone	2
15.	Shale and sandstone	67
16.	Limestone	1
17.	Shale (?)	2
18.	Limestone	15
19.	Sandstone (?)	4

The hole was drilled several feet deeper than this but the drillers reported the rest to be "Granite." The latter is without much doubt the cherty Lower Carboniferous limestones. A four-foot bed of coal was encountered in the J. W. Hammett well about a mile north of the Hammett drill hole and at about the horizon of the Bevier coal bed. The latter outcrops also at several places on this horizon on the farm of Major Newton about a mile north of the last locality. It is mined for local fuel at a few places in the vicinity. In the extreme southwestern corner of section 23 of the same township and range, the limestone underlying the Bevier coal bed is exposed in the hill just nort of the road 300 feet west of the bridge over the East Fork of Chariton river, and the coal is exposed on the western side of the road just as it turns into the north and south road 900 feet from the bridge. About a mile further west it is exposed in the road about 25 feet above the level of the river bottom.

Beneath the river and Huntsville sandstones and shales are abundantly exposed and sandstone blocks are prevalent on

the slopes in the southern part of town. The Bevier coal lies near the level of the branch at the gas works. The vertical distribution of the rocks in the vicinity is given in sections I, II and III.

West of Huntsville, between the township line on the south and East Fork on the north, exposures of Coal Measure rocks are rare. The drift covers all the older rocks. North of the river toward the western part of the township the Middle Coal Measure rocks are exposed on the higher hills and occasionally the shales of the Lower Coal Measures can be seen. In Tp. 54 N., R. XV W., Sec. 20, Prof. Gordon records an outcrop of two feet of black shale underlain by three feet of coal in thin layers interlaminated with clay and shale. It lies about thirty feet below the top of the Lower Coal Measures and therefore near the horizon of the Bevier coal bed. West of this no more exposures of Lower Coal Measure rocks were seen east of the bluffs on the eastern side of the Middle Fork of Chariton river.

During the year 1868, or about that time, a deep drill hole was sunk at Randolph Springs. If any record was kept it is now lost and nothing reliable has been learned of what was passed through. The hole was bored for oil and little attention was paid to the rocks. A fact which is worthy of consideration in regard to the reports of coal beds in this as well as a large number of drill holes which were sunk during the petroleum excitement about this time, is that the drillers seem to have reported coal wherever the drillings were black.

A few years ago a churn drill hole was put down in search of coal in Tp. 54 N., R. XVI W., Sec. 36, about a mile east of Clifton Hill station. A record was kept but was subsequently lost. The hole was sunk to a depth of more than 100 feet but no coal was encountered. The top of the hole is about 680 feet A. T. The horizon of the Bevier coal bed at its nearest outcrop, almost three and one-half miles southeast of this is about 735 feet A. T. Without a dip of the coal, therefore, the top of the drill hole would be about forty-five feet below the horizon of the coal, and allowing about ten feet for soil and superficial material the coal would have to dip 70 feet within that dis-

tance in order to have been struck in the drill hole. It is true that this is a very slight dip but the few facts gathered from outcrops on the south side of the river, south of Randolph Springs, do not indicate that there is such a dip. At its first outcrop west of this it is about sixty-five feet lower than at its first exposure eastward, but there is nothing in this to indicate that nearly the whole dip is east of the drill hole and that west of it the coal bed is horizontal. The evidence points to the conclusion that the top of the drill hole is below the horizon of the coal bed.

In Tp. 54 N., R. XVI W., Sec. 31, Ne. ¼ a bed of coal is mined which is correlated with the Bevier bed. On the bank of the Middle Fork of Chariton river, a little farther west, the same coal bed is mined in a number of places. It is overlain by several feet of shale and is underlain beneath the clay bed by limestone. No further exposures of Lower Coal Measure rocks were seen up the river from this place though careful examinations were not made. At Thomas Hill* a village about three miles up the stream from where the river enters the sheet, the Bevier coal is reached by a shaft fifty feet deep sunk near the level of the river floodplain.

The Coal Measure rocks above the Bevier coal bed are not often exposed in the northern part of the quadrangle. The limestones overlying the Macon City and Summit coals outcrop in the roads in a few places but generally the rocks are pretty well hidden by the superficial material. The Macon City coal with its accompanying limestone crops out in the road on the western side of the southwest quarter of Section 23. In Sections 20 and 21 both the Summit and the Macon City beds are occasionally exposed, the former near the tops of the hills. The Macon City bed is exposed at several points in the road near the Newton place in Sections 11 and 14.

In Township 54 N., Range 16 W., a very few exposures of the Middle Coal Measure rocks occur. In the southeast quarter of section 9 of this township coal was mined at one time in the bed of Rocky branch. From the topographic position it is

* See Report on Bevier Sheet, Mo. Geol. Survey, 1894.

thought it probably belongs to the Macon City bed. It is also reported that coal can be seen in the bank of the river at the William bridge in section 15. This also is near the horizon of the Macon City coal. At Thomas Hill, a mile and a half up the river from the northern side of the sheet, the Summit coal is exposed in the hillside about twenty feet above the top of the shaft and thirty feet above the river floodplain.

SECTIONS IN TOWNSHIP 53 N., RANGES XIV, XV AND XVI W.

VI. Outcrop.

(Tp. 53 N., Range XIV W., Sec. 29, Se. qr. Nw. ¼.)

Bottom of section is about 795 feet A. T.

		Feet.
1.	Concealed	
2.	Limestone, crumbling, fragmentry, with some massive layers	8
3.	Concealed	½
4.	Limestone, hard, blue, fine textured, about	1½
5.	Shale, black, fissile	2
6.	Coal (Summit bed)	1
7.	Clay	1
	Interval to top of Lower Coal Measures, about	25

The shaft at Elliot station on the Missouri, Kansas and Texas railroad is about two miles east of the eastern boundary of the sheet. Its record is here introduced to show the character of the rocks and for comparison. It is about as follows:

VII. Record of Elliot Shaft.

Top of shaft is about 860 feet A. T.

		Feet.
1.	Surface clay	24
2.	Sand	1
3.	Clay and bowlders	10
4.	Clay and gravel (water bearing)	4
5.	Shale	9
6.	Limestone	1
7.	Shale	2½
8.	Limestone	6
9.	Sandstone (upper part harder than lower)	12
10.	Shale, hard, blue	6
11.	Limestone	4
12.	Shale, black, fissile	2
13.	Coal *(Summit bed)* about	1
14.	Clay	2½
15.	"Conglomerate"	4

		Feet.
16.	Shale, sandy	6
17.	Granite-like rock (limestone)	4½
18.	Shale, black, fissile	4
19.	Coal *(Macon City bed)*	1¼
20.	Clay and conglomerate. *(Top of Lower Coal Measures.)*	4
21.	Shale	18
22.	Coal *(Bevier bed)*	4
23.	Clay	1
24.	Limestone	

In Tp. 53 N., R. XIV W., Sec. 30, S. W. qr. N. W. ¼, the Summit coal outcrops in the bank of the branch. It is here about ten inches thick and is overlain by two feet of black fissile shale, as in the Elliot shaft, with three and one-half feet of hard, blue compact limestone overlying the shale.

In Tp. 53 N., R. XVI W., Sec. 25 N. E. qr. Se. ¼, the overlying limestone of the Macon City coal is exposed in the bluff near the level of the creek bottom, and about half a mile west of this the following rocks are exposed:

VIII. Record of Outcrop.

(Tp. 53, N., R. XVI W., Sec. 33, Nw. qr. Sw. ¼.)

Bottom of Section is about 690 feet A. T.

		Feet.
1.	Limestone	
2.	Concealed	10
3.	Limestone	3½
4.	Shale, black, fissile	2
5.	Coal *(Summit bed)*	1
6.	Clay	2
7.	Clay	

About 250 yards northeast of this, J. W. Cross operates a coal mine. This bed of coal is from two to five feet thick and is overlain by black shale and that in turn by limestone. The limestone is equivalent to No. 1 of the last section. The coal lies at the top of the concealed space No. 2. It apparently is of very limited area since it does not occur under the limestone at the locality where the section was measured, and was not met with at any other locality within the quadrangle.

Where the road descends the hill, Tp. 53 N., R. XVI W., Sec. 27, the following rocks were seen:

Section IX.

		Feet.
1.	Concealed from top of hill	25
2.	Limestone	8
3.	Shale, yellowish	15
4.	Limestone	2
5.	Black streak with yellowish shale below	12
6.	Limestone	4
7.	Black streak *(top of Lower Coal Measures)*	
8.	Concealed to creek	35

In Section 32 of the same township the following sequence of rocks is exposed:

X. Record of Outcrop.

(Tp. 53 N., R. XVI W., Section 32, Sw. qr. Ne. ¼.)

Bottom of section is about 665 feet A. T.

		Feet.
1.	Concealed	
2.	Limestone	8
3.	Shale, black, fissile	2
4.	Coal *(Macon City bed) top of Middle Coal Measures*	2
5.	Concealed with shale in places	28
6.	Shale, black, fissile	½
7.	Coal *(Bevier bed)*	8

In a well in the northwest quarter of this section the Summit coal was struck. At the foot of the hill 300 feet east of the well the Bevier coal is exposed and mined. The interval between the two coal beds is about 50 feet with no Coal Measure rocks exposed excepting about 15 feet of shales overlying the Bevier coal. In the northern part of the township a coal bed is exposed in a number of places. It lies about 50 feet above the Bevier coal bed and is probably the Summit coal.

SECTIONS IN TOWNSHIP 52 N., RANGES XIV, XV AND XVI W.

The most important sections of Middle Coal Measure rocks of that part of Township 52 N., Range 14 W., lying within the quadrangle are those exposed in the coal shafts and drill holes at and in the vicinity of Higbee. The shaft of the Higbee Coal and Mining Company of Higbee is on the south side of the railroad about half a mile west of the town. The record is as follows:

XI. Record of Outcrop.

(Tp. 52 N., R. XIV W., Sec. 13, Ne. qr. Se. ¼.)
Top of shaft is about 865 feet A. T.

		Feet.
1.	Clay	70
2.	Shale and sandstone	3
3.	Limestone	7
4.	Clay, blue	3
5.	Limestone	6
6.	Shale	6
7.	Sandstone	7
8.	Limestone, hard	8½
9.	Shale, black, fissile	1½
10.	Coal (*Summit bed*)	1
11.	Clay	4
12.	"Conglomerated rock"	14
13.	Shales	2
14.	"Hard rock" (Limestone)	3
15.	Shale, black, fissile	3
16.	Coal (*Macon City bed*)	1½
17.	Clay (*Top of Lower Coal Measures*)	8
18.	Shales	30
19.	Coal (*Bevier bed*)	3½
20.	Clay	

A drill hole was sunk in prospecting for coal, about the time this shaft was sunk, a mile north of Higbee. The record here is as follows:

XII. Record of Drill Hole.

Tp. 52 N., R. XIV W., Sec. 8, Ne. qr.)
Top of hole is about 870 feet A. T.

		Feet.
1.	Clay	68
2.	Shell rock	20
3.	Clay	4
4.	Limestone	7½
5.	Clay	17
6.	Limestone	3½
7.	Shale and coal (*Summit bed*)	1½
8.	"Conglomerated rock" (limestone) (?)	14½
10.	Shale, black, fissile	2
11.	Coal (*Macon City bed*)	1
12.	Shale	31
13.	Coal (*Bevier bed*)	3
14.	Clay	1

The McDonald shaft, owned and operated by the Interstate Mining Company, is located on the Missouri, Kansas and Texas railroad about two miles south of Higbee, in Tp. 52 N., R. XIV W., Sec. 19, Ne. qr. Sw. ¼. The record is as follows:

XIII. Record of McDonald Shaft.

Top of shaft is about 810 feet A. T.

		Feet.
1.	Clay	4½
2.	Limestone and gravel	1½
3.	Sand and gravel	2
4.	Clay	2
5.	Limestone	4
6.	Clay	8½
7.	Limestone	8
8.	Clay	20
9.	Limestone	3½
10.	Shale, black, fissile	½
11.	Coal *(Summit bed)*	1
12.	Clay	2½
13.	"Conglomerated rock"	10
14.	Limestone	1½
15.	Shale, black, fissile	1½
16.	Coal *(Macon City bed)*	2
17.	Clay, *Top of Lower Coal Measures*	2½
18.	Shale, drab	30
19.	Coal *(Bevier bed)*	4½
20.	Clay	2

The three foregoing records were furnished to the survey by Mr. Chas. Evans of Higbee, the present State Mine Inspector, who superintended the work of sinking the shafts and the drill holes. They were reported from memory.

In the southwest quarter of section 31 of the same township the Macon City coal is exposed at the base of the bluff. It is reported to be about eighteen inches thick.

In Tp. 52 N., R. XV W., Sec. 1, Sw. qr. Ne. ¼ there is an exposure of limestone, shale and coal which is correlated with the Summit coal and its associated limestone and shale. The Macon City coal has been mined in the southeast quarter of the northwest quarter of section 2, about half a mile down the creek from the last, and about eighty yards below the Riley Graves coal bank, the following section was measured:

XIV. Record of Outcrop.

(Tp. 52 N., R. XV W., Sec. 3, Ne. qr. Ne. ¼.)

Top of section is about 785 feet A. T.

		Feet.
1.	Concealed	8
2.	Limestone	3½
3.	Shale, black, fissile	2
4.	Coal *(Summit bed)*	1
5.	Concealed	12
6.	Limestone	1¼
7.	Shale, black, fissile	4½
8.	Smut—*Macon City coal bed*	
	Top of Lower Coal Measures	
9.	Shale, sandy	25
10.	Shale, drab and ash colored	6
11.	Coal *(Bevier bed)*	3¼
12.	Clay	1
13.	Limestone (exposed to bed of creek)	1¼

The Summit coal is exposed in the bed of the branch west of the church in section 5 of this township at an elevation of about 720 feet A. T. The rocks rise eastward. A mile east of the last in the next branch, the Bevier coal bed lies at an elevation of about 750 feet making necessary a rise of the rocks of more than fifty feet in this distance. In section 4, near where the branch crosses the mid-line, the following rocks are exposed all of them being below the Bevier coal bed:

XV. Record of Outcrop.

(Tp. 52 N., R. XV W., Sec. 4, Nw. qr. Nw. ¼.)

Bottom of section is about 740 feet A. T.

		Feet.
1.	Limestone	1
2.	Limestone, shaly, decomposed	1
3.	Limestone, hard, blue	1¼
4.	Shale, black, fissile	3¼
5.	Clay, shaly	1

Several years ago a shaft was sunk about three-quarters of a mile west of Yates station, on the Chicago and Alton railroad. After sinking the shaft to a depth of about eighty feet the company doing the work abandoned it. Some farmers in the neighborhood, in the hope of striking the Bevier coal bed

drilled a hole in the bottom of the shaft to a depth of about 170 feet from the surface.

The record reported to the writer by R. D. Broaddus of Yates is as follows:

XVI. Record of the Yates Shaft and Drill Hole.

(Tp. 52 N., R. XX W., Sec. 16, Sw. qr. Nw. ¼.)

Top of shaft is about 840 feet A. T.

		Feet.
1.	Clay, with bowlders	77
2.	Sandstone	7
	Bottom of shaft and top of drill hole.	
3.	Sandstone	27
4.	Clay	1
5.	Limestone, hard	8
6.	Clay	4
7.	Limestone	5
8.	Clay	2
9.	Limestone	7
10	Coal	1¼
11.	Shale	5
12.	Limestone	4
13.	Shale	14
14.	Limestone	3½
15.	Shale	15

If the Bevier coal bed remained about horizontal at its average elevation along Silver creek it would have been encountered here about thirty feet below the bottom of the shaft. The record shows twenty-seven feet of sandstone here and beneath that clay and limestone, which it does not require a great stretch of the imagination to correlate with similar rocks underlying that coal at all of its outcrops. It is probable, therefore, that at this point the Bevier coal bed has been replaced by sandstone. It is reasonably sure, when the elevation of the outcrops of the rocks on both sides of the shaft are considered, that the bottom of the drill hole is below the horizon of the Bevier coal bed. None of the regular Middle Coal Measure rocks were encountered in the shaft.

About a mile and a half southeast of Yates, on the Hudson property, the rocks are exposed about as follows:

XVII. Outcrop of the Hudson Land.

Bottom of Section is about 755 feet A. T.

		Feet.
1.	Limestone, containing spots of decomposed pyrite	1½
2.	Shale, black, fissile	1½
3.	Coal *(Summit bed)*	1
4.	Clay and sandy shale, about	8
5.	Limestone	2
6.	Shale, black, fissile, about	2
7.	Coal *(Macon City bed)*	1½
	Top of Lower Coal Measures.	
8.	Clay and shales, about	10
9.	Coal, about	4

From this point the rocks dip rapidly southward (Fig. 34) for a short distance and then lie horizontal. At Forbis' mill,

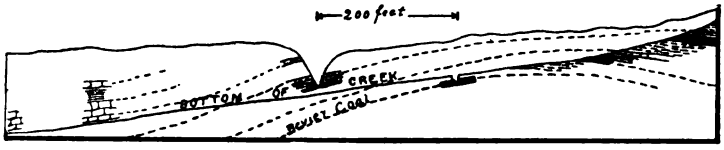

Figure 34. Showing southward dip of rocks from the Hudson outcrop.

n Tp. 5? N., R. XV W., Sec. 28, Ne. qr., the sequence is approximately as follows:

XVIII. Outcrop near Forbis' Mill.

Base of section is about 710 feet A. T.

		Feet.
1	Concealed	
2.	Limestone	9
3.	Concealed (shales?)	15
4.	Limestone, with spots of pyrite	8
5.	Shale, black, fissile	2
6.	Coal *(Summit bed)*	1
	Interval to top of Lower Coal Measures	15

In Sec. 33, Sw. qr. Nw. ¼, the same bed of coal is exposed, overlain by the same characteristic limestone of the above section. Over the whole southwestern part of the quadrangle this limestone is easily identified by its massive character, and by the occurrence in it of abundant spots of pyrite which, on exposure, cover the face of the rock with red streaks.

Two and one-half miles southwest of Forbis' mill the following outcrop occurs:

XIX. Record of Outcrop.

(Tp. 52 N., R. XV W., Sec. 31, Se. qr. Nw. ¼.)

Bottom of section is about 720 feet. A. T.

		Feet.
1.	Concealed	
2.	Limestone, blue, hard, contains pyrite spots	3
3.	Shale, black, fissile at botom, argillaceous at top	2
4.	Coal *(Summit bed)*	½
5.	Clay	15

In Tp. 51 N., R. XV W., Sec. 5, Nw. corner, the following rocks are exposed in the road:

XX. Record of Outcrop.

Top of section is about 760 feet A. T.

		Feet.
1.	Concealed	8
2.	Limestone	8
3.	Shales, sandy	10
4.	Limestone	8
5.	Shale	3
6.	Coal *(Summit bed)*	1
7.	Concealed	12
8.	Limestone	2½
9.	Shale and coal *(Macon City bed)*	3½
	Top of Lower Coal Measures.	

Prof. Broadhead measured the following section in the Ne. ¼ of section 7:

XXI. Record of Outcrop. From G. C. Broadhead.

(Tp. 52 N., R. XV, Sec. 7, Ne. ¼.)

		Feet.
1.	Shales, argillaceous, dove colored	5
2.	Coal, bituminous, lower part shaly	1
3.	Clay	2
4.	Concealed with sandy shales in lower part	8
	Interval to top of Lower Coal Measures, about	80

It is believed that the rocks of this section lie about 35 feet above the upper limestone of the preceding section. This statement is based on an outcrop occurring in the southwest corner of section 7. In the road at this place a dark streak among some sandy and argillaceous shales is visible. The streak is about 35 feet above a bed of limestone outcropping

in the branch 150 feet eastward. The interval given may be wrong but the rock is evidently the upper limestone bed of the preceding section.

Broadhead says that it is not possible to make this coal agree with his general section. It is thought by him to occupy a higher stratigraphic position than any of the other coals. It is probably on about the same horizon as the Beech coal bed.

In the Nw. ¼ of the Sw. ¼ of Section 30, Township 52 N., Range 15 W., about ¼ mile east of Beech's coal mine the following rocks are exposed:

XXII. Record of Outcrop.

Top of section is about 750 feet A. T.

		Feet.
1.	Sandstone (exposed)	8
2.	Limestone	7
3.	Clay and shale (exposed)	5
4.	*Interval to top of Lower Coal Measures*	35

The bed No. 2 is correlated with No. 2 of section XX and the sandstone above it with the rocks in the section copied from Broodhead.

About half a mile south of this locality the Summit coal outcrops in the bed of the creek. The Beech coal shaft is located on top of the hill just across the range line west of the last section. It is twenty feet deep, sunk through sixteen feet of soil and shale and four feet of coal. The coal is only a few feet above the top of the last section. It is not seen to outcrop near the shaft. The same coal bed is operated on the Briggs farm about half a mile northwestward. These are the only exposures of this coal met with within the area unless those referred to above (in the Broadhead section and in southwest corner of section 7) be the attenuated edges of the basin. There is an exposure of dark shales in a ditch by the roadside in Tp. 52 N., R. XV W., Sec. 18, nw. corner at an elevation of 780 feet A. T. and another in a bed of sandy shales about half a mile southwest of Armstrong station. These are probably on the same horizon. In the adjacent township to the west in section 36, the Summit coal is exposed at one or more places at an elevation of about 720 A. T.

In section 16 of this township, just southeast of the center, the following order of strata is disclosed:

XXIII. Record of Outcrop.

Top of No. 2 of the section is about 765 feet A. T.

		Feet.
1.	Concealed	
2.	Limestone, hard, compact, blue	2
3.	Concealed	20
4.	Limestone	1
5.	Smut, *Top of Lower Coal Measures*	
6.	Shales, argillaceous with interbedded sandstone	10

The following section was measured by Norwood and published in the report of the Geological Survey for 1873–74, page 208:

XXIV. Record of Outcrop. From Norwood.

(Tp. 52 N., R. XIV W., Sec. 20, Nw. qr.)

		Feet.
1.	Slope	20 to 40
2.	Limestone, rough-bedded, fine grained, dove and gray, abounding in masses of *Chætetes milleporaceous*	5
3.	Shale, argillaceous, light blue and ochre	8
4.	Clay	3
5.	Slope	12
6.	"Rhomboidal limestone"	½-2
7.	Shale, drab	1
8.	Shale, bituminous	2
9.	Coal "Coal B" *(Summit bed)*	½
10.	Slope	8
11.	Shale, greenish, arenaceous, with thin beds and nodules of bluish drab limestone thickly distributed through the clay or shale	5
12.	Limestone, in three layers, hard, compact, fine-grained, chocolate and grayish	1¾
13.	Shale, olive and slightly calcareous	2½
14.	Shale, dark blue with knife edges of coal (Coal C) *(Macon City bed)*	1
15.	Slope	15
16.	Sandstone, gray, indurated	½
17.	Sandstone	10½
18.	Sandy shale	5

This is a compiled section from outcrops occuring near the locality given above.

On Doxy fork and in Tp. 52 N., R. XVI W., Sec. 15, Ne. qr., Norwood measured the following section:

XXV. From Norwood.

		Feet.
1.	Sandstone, shaly and shale	
2.	Limestone, rough, light drab to gray, fine grained, specks of calcite disseminated	2
3.	Shale, abounding in olive and dark calcareous spots. *Spirifer planoconvexus* and other fossils	3
4.	Coal smut—not persistent	
5.	Limestone, nodular, ash, drab and gray argillaceous abounding in *Fusulina*	½
6.	Shale and masses of buff cellular limestone	¼
7.	Limestone, fine grained, drab	2
8.	Shale and thin beds of limestone	1
9.	Limestone, irregularly bedded. The top is very light drab and shelly while the lower part is compact, fine grained and bluish	6
10.	Limestone, blue and dove-colored	1
11.	Limestone, bluish gray	1
12.	Chætetes limestone, division A	3
13.	Chætetes limestone, division B	2½
14.	Slope, argillaceous shale is seen at top	17
15.	Limestone, rhomboidal	2
16.	Shale argillo-bituminous	2
17.	Coal, B. (*Summit*)	1

THE MOBERLY SANDSTONE.

The outcrops of this sandstone are numerous, though in many places there are no features to distinguish it from the regular interbedded sandstones occurring in the Lower and Middle Coal Measures. As a general thing, however, it is coarser, more heavily bedded and often shows cross bedding, while the sandstones regularly conformable and interbedded with the other strata are rarely or never cross bedded, are generally thinly bedded and are fine grained. The most significant exposure of this sandstone within the area of the sheet is shown in figure 35. The outcrop is in Tp. 53 N., R. XIV W., Sec. 18, Sw. corner and the figure shows the relation of beds thence north-

Figure 35.

ward to Sweet Springs creek and southward about 1,300 feet. The limestone at the base of the section is correlated with the limestone underlying the Bevier coal bed. The latter is

exposed in the bed of the branch about 1,300 south of the outcrop. In a small hollow 300 feet west of this outcrop the sandstone, conglomerate and limestone are exposed showing the same succession and the same character of rocks. The limestone weathers into the rugged pitted mass which is characteristic of the underlying limestone of the Bevier coal bed wherever exposed.

The line of contact between the conglomerate and the limestone has a northward dip, but the limestone bed itself remains horizontal until replaced by the sandstone. On Sweet Spring creek, a mile north of this place, the sandstone extends from the top to the base of the bluffs in a bed about fifty feet thick, and between the two places there are many outcrops of sandstone but none of any other rocks.

The base of the bluffs is about thirty-five feet lower than the conglomerate in the section. An exposure much like this one was measured by Gordon in Section 8 Tp. 54 N., R. 14 W. Prof. Gordon does not give the thickness of the beds in every case but the succession is the significant part. It runs as follows:

XXVI. Record of Outcrop.

(Tp. 53 N., R. XIV W., Sec. 8, Ne. qr. Sw. ¼).

Base of outcrop is about 740 feet A. T.

	Feet.
1. Concealed	
2. Shaly rock, dark	
3. Shales, sandy, micaceous	
4. Sandstone	3
5. "Limestone conglomerate"	2

Several years ago a shaft was sunk at Moberly. The record was reported by E. Silk. It is stated that there were eighty-five feet of clay and sand, underlain by 115 feet of sandstone, and at the base of this rock a bed of conglomerate about two feet thick. Lower down beds of limestone and a few thin beds of coal were encountered. Winslow reports the finding of a contact similar to the one described above, in western Monroe county, several miles east of Moberly, where there is a clear uniformity between the sandstone with its basal con-

glomerate and the underlying rocks. Another contact similar to those just described is partly exposed about 1,500 feet down the creek from the brick works situated in the hollow about a mile southwest of Moberly. The belt of sandstone connects all these localities continuously.

Down Sweet Spring creek for about two miles below where the stream passes the 14-15 range line the bluffs on the southern side are sandstone from top to base and in the hollows for a little more than a mile south of the creek sandstone is the only rock exposed. At the Bagby mill this rock outcrops in the road on the northern side of the creek. In a bluff near the church about 1,500 feet southwest of the mill a thickness of twenty feet of the same formation is exposed.

In Tp. 53 N., R. XV W., Sec. 6, Sw. ¼ and continuing down the creek half a mile, the sandstone, false-bedded and interbedded with shale, is exposed in the bluffs to a thickness of about fifty feet and again in the northwest quarter of section 12 in the township just to the west. One mile north of this locality a limestone is exposed in a hollow at an elevation of about 700 feet A. T. It is not possible with the data now at hand to determine whether this is outside the limits of the sandstone belt or whether it is near its edge and has been uncovered by the erosion of the thin edge of the sandstone from above it, neither do we know just where to place the limestone in the section.

Further down the stream the bluffs are low and the topography rolling. The sandstone beds do not appear so prominently, though none of the regular beds of limestone were found. The sandstones are exposed in sections 16 and 17, the bluffs in the latter being wholly made up of such rock. In no place, on approaching the belt of sandstone, do the regular coal measures show any dip in either direction to indicate an anticline or syncline running along the axis of the sandstone belt. The transition on the surface from heavy cross-beded sandstone to the regular limestone and shale beds of the undisturbed Coal Measures is sudden but without sign of crustal movements. No sandstone bed which compares with

it in thickness and character is found among the other rocks. These facts, together with the undoubted unconformity shown in a few places, and the fact that the belt is continuous, leaves little doubt that the whole belt represents a distinct period of deposition, and that the sandstone fills a channel of erosion in the older Coal Measure rocks.

Another sandstone which very probably belong to the same series of deposits is exposed in a small tributary of Bonne Femme creek about two and one-half miles southwest of Yates.

Figure 36 shows the relation of this rock to the lower beds displayed in an outcrop on the east bank of the creek near where the half-mile line running east and west through section 3, T. 52 N., R. XV W. crosses the branch and Fig. 37 shows the

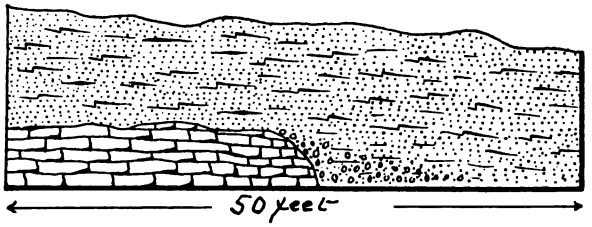

Figure 36.

relation on the opposite side of the branch at the mouth of a small ravine about 1,000 feet south of the former outcrop. The contact at the last outcrop is not exposed. There is no sign whatever of faulting, and since the contact in the first case is unmistakably an unconformable one and since the banks of the branch between the two points are composed of sandstone, the latter is presumably of the same nature.

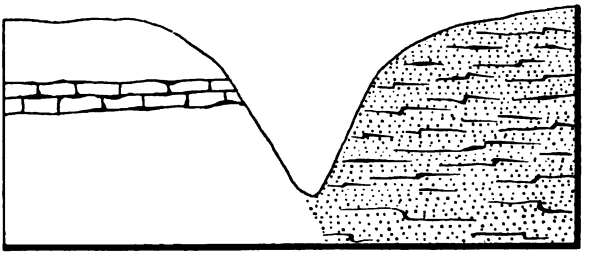

Figure 37.

About a mile southwest of this locality a coarse, heavily bedded reddish sandstone was seen but no contacts with other rocks were exposed. It was not traced further in this direction. It will be remembered that there is a rather heavy bed of sandstone in the shaft and drill hole at Yates and that the regular Middle and apparently the Lower Coal Measure rocks down to and including the Bevier coal bed were absent and the place occupied by sandstone. This may be explained by supposing them to have been cut out by a former drainage system and the channel subsequently refilled with sand. Direct connection northward with the Moberly sandstone belt could not be traced and the evidence is pretty conclusive that it does not exist within the area of the quadrangle. If it is connected with that sandstone it must be through a channel entering it somewhere west of the area.

SUPERFICIAL DEPOSITS.

These consist of glacial deposits and alluvium. The glacial deposits, according to Todd* consist of two divisions, a lower ice-laid drift or till and an upper water-laid drift or the gray loamy clay.

The Till. The till consists principally of sand and clay with a rather low percentage of gravel. Occasional bowlders of both northern and local origin occur in it, those of local origin being the most abundant and largest. Very rarely larger bowlders of northern origin are met with. In such cases they are either granite, quartzite or diabase. During the prosecution of the field work half a dozen large bowlders were met with. The largest one was found about a mile east of Higbee. It contained about 150 cubic feet. Several smaller ones were found along Silver creek west of Higbee. The average thickness of the till in Randolph county will probably not exceed 20 feet. The upper phase of the drift, the gray loamy clay has a maximum thickness of at least 50 feet and where it has suffered no erosion it may be thicker. The total thickness of superficial deposits at Higbee and Yates is about 70 feet but

*Report Missouri Geol Sur., Vol. IX, p. 152

there are no facts on record to show how much of this is clay and how much is till. At the Elliott shaft about four miles northeast of Higbee the gray clay is about 25 feet in thickness and the till about the same. The latter is thicker, there, apparently, than at Higbee. On the ridge in the vicinity of Huntsville and eastward the total thickness of unconsolidated material is about the same as at Elliott, though the relative proportion of the two phases is not known.

The Gray Loamy Clay. This deposit is sufficiently described by its name. It consists principally of quartz in an an exceedingly fine state of division. Microscopic examination shows a rather small percentage of other constituents. There does not appear to be any noticeable percentage of undecomposed rock present. It is not, therefore, a typical rock flour.

In the vicinity of the streams this formation approaches the typical loses of the Missouri and Mississippi rivers in character, and in the extreme southwestern corner of the quadrangle it gives place to the latter.

STRUCTURAL GEOLOGY.

The geologic structure of the area is very simple. There is a gradual dip of the rocks westward or northwestward. The elevation of the Bevier coal bed at the northeastern corner of the sheet is about 735 feet A. T. and at the northwestern corner it is about 640 feet A. T. At Higbee the same coal bed is about 690 feet A. T. and at the Graves mine, on Silver creek, it is about 710 feet A. T. From this point it gradually descends passing below the bed of the creek at the Fullington stripping in Tp. 53 N., R. XV W., Sec. 34. From here it dips about with the bed of the creek and at the Ware drift in the northwest quarter of the next township to the west is about 640 feet A. T.

From Higbee southward the Bevier coal bed rises very slightly. At the shaft of the Higbee Coal and Mining Company it lies about 690 feet above sea level. At the McDonald shaft, two miles south of Higbee, it is about 710 feet above

the same datum and at Russell switch near the southern line of the quadrangle it is 25 or 30 feet higher. From Higbee westward there is a rise of the coal bed. At the Hudson farm, one and one-half miles southeast of Yates, the Bevier coal bed lies at an elevation of about 750 feet. Southwestward from this locality the rocks dip rapidly in the same direction for a few hundred feet then more gradually to the vicinity of the Forbis mill south of which they lie about horizontal. Directly westward from the Hudson farm there are very few outcrops to indicate the structure, but from Armstrong westward the rocks show a gradual dip southwestward. Northwestward from the Hudson farm the rocks dip very slightly.

There is therefore an uplift running across the southern part of the sheet the axis of which passes through the Hudson farm and runs in a Nw. Se. direction crossing the M., K. and T. railroad near Russell switch. It dies out toward the northwest being imperceptible beyond Roanoke. From Huntsville, where the Bevier coal bed lies about 730 feet above sea level westward, the rocks lie almost perfectly horrizontal for a distance of about two and a half miles at least. For the next mile or two there are no outcrops which furnish a clue to the structure, but beyond Clifton hill there is a dip, apparently rather rapid, to the west northwest, so that at the next point where the Bevier coal bed is exposed, near the western line of the area it lies at an elevation of about 645 feet above sea level.

UNCONFORMITIES.

There are two unconformities in the Paleozoic section of the Huntsville quadrangle; that between the Lower Carboniferous limestone and the Coal Measures, and that between the Coal Measures and the Moberly sandstone. Each is the result, however, of nothing more than an elevation above sea level and subsequent erosion. No folding or other orogenic disturbance occurred in the meantime. The oscillations of level which have occurred since the physical history of the area began have been a slow areal submergence and emergence unaccompanied by lateral pressure.

ECONOMIC GEOLOGY.

The deposits of economic importance within our area are soils, coals and clays.

SOILS.

The basis of all soils is the product of rock disintegration. Rocks may disintegrate, and the soil thus made may remain in the place occupied by the rock from which it was derived, or the soil may be carried away from its parent locality by the various agencies of natural transportation and be dropped in another place. The former are called sedentary or residuary soils and the latter transported or foreign soil. A pure sedentary soil probably has more of a theoretical than actual existence. In the gradual breaking up of the rocks, there is an inevitable creep down the slopes, which results in a more or less thorough mixing of the products of the various kinds of rock on the slopes. It should not be expected therefore in a region of so-called sedentary soils that there would be a complete and sudden change from soil of one kind to that of another in passing from an outcrop of one kind of rock to that of a different kind. Another condition of things aiding in producing a soil of various constituents is that the soil at any particular place (leaving out the creep) contains constituents derived from rocks originally overlying the present country rock. These originally overlying rocks may have been of great thickness and of greatly varying character.

There are no sedentary soils within the area of the Huntsville quadrangle.

Of the foreign soils of the area there are two kinds: 1st, those derived from the various deposits of the glacial period; 2nd, those derived from the alluvial deposits of the streams. Soils of the first or drift deposits cover by far the larger part of the area. Two phases of drift deposits are represented, and each has its characteristic features. The soil derived from the drift clay is cold and close. It consists of a tough, yellow clay

with so little sand that the drainage is poor. It is the poorest soil in the area. When it is not cultivated, it is covered with a dense thicket of white oak saplings. It occupies the belt of rugged topography of the second division of the topographic features of the area. After several years of careful cultivation it becomes a good grass producer. The soil derived from the deposits representing the other phase of the drift are the most productive within the area. They are the basis of its agricultural prosperity. They represent a distinct phase of glacial deposits in the area. They apparently become better soils as the streams are approached and as the Missouri river is approached. In the southwestern part of the area they are apparently richer than elsewhere. On the supposition that this deposit is the equivalent of the loess, so well developed along the Missouri river, this is what should be expected. As that stream is approached it becomes more like the typical loess which constitutes the richest soil within the state. Further away from that stream it would be close and more argillaceous. It is easily tilled and produces good crops of both grain and grasses. It covers the whole area of the sheet excepting the floodplains of the streams and the small areas along the eastern side and, in fact, it is not perfectly clear that the so-called clay soils of the margin of the "grand divide" are not the argillaceous phase of the higher deposit when it has been eroded and probably mixed with the clay.

The alluvial soils are confined to a limited area. The topographic sheet shows their distribution. They are of a black or ashen color and are, when well drained, very fertile. So far they have been insignificant as a wealth producer on account of lack of drainage. During stages of excessively high water, the greater part of these floodplains is submerged, and when not overflowed from the streams, water stands on them in many places from lack of outlet to the streams, as well as from the close clayey character of the deposit. The surface drainage is the only drainage they have and this is exceedingly poor. The narrow strip of recently built floodplain along the streams is sufficiently well drained

to support a luxuriant growth of forest trees. The rest of these floodplains is bare of timber though they grow a course grass. During comparatively dry seasons they produce good crops but during wet seasons they produce nothing. By continued cultivation they become better producers. The stirring of the top makes it capable of draining off part of the water and hastens evaporation. With proper ditches, levees and careful cultivation they may be made valuable. On account of the exceedingly close character of the soil tile drainage will probably be difficult.

COAL.

Coal is mined on a large scale at a great many localities within the area. At some of them it is carried on on an extensives cale, the land and equipments constituting valuable pieces of property. Many of the openings, however, are small country mines which are operated only at widely separated intervals.

Mining is prosecuted at present almost exclusively on one bed of coal, the Bevier bed. It lies so near the surface that it outcrops abundantly in the hillsides, and being rather a thick bed it is easily located. It rarely underlies more than 175 feet of overlying rock in the areas where it is known to occur and on the average its depth is probably not more than 100 feet.

There are four other beds outcropping within the area, from all of which coal has been mined though to an exceedingly small extent. They all overlie the Bevier bed and are, in ascending order, the Macon City, the Summit, the Cross and the Beech coal beds.

The Bevier coal bed is the lowest of workable thickness known to underlie any considerable part of the area of the sheet. The oldest mines in this part of the state are operated in this seam. The first coal mines in the vicinity of Huntsville were opened by Chapman and Reece but the date is not given.*

In 1878 there were shipped from Huntsville about 85,000 tons of coal which probably represents the total shipments from the area of the sheet at that time. The industry has advanced gradually, though slowly since then. During the year ending

*History of Randolph and Macon Counties, p. 210.

June 30, 1897, there were produced from the Randolph county mines about 220,000 tons of coal.

The most extensive mines now in operation are in the vicinity of Huntsville and Higbee. About two miles east of the former on the Wabash railroad near the midline of section 32 is a shaft operated by Breckenridge of Huntsville. It was sunk in the summer of 1890, and is supplied with a double hoist with steam machinery for handling the coal, and it is connected with the railroad by a switch. The shaft is about ninety feet deep, a record of which has already been given (see section II). The coal bed, four feet and six inches thick, is divided into two benches, the upper of which is three and one-half feet thick. The mine is operated continuously throughout the year and furnishes employment to about eighty men. The product is shipped to Kansas City and local points and is used almost exclusively as a steam producer.

About half a mile west of this is old No. 2, which has been abandoned for several years. It was about the same depth and operated on the same bed.

Nos. 2½, 3 and 4 are located westward along the railroad. The first named has been abandoned many years, the next was operated until about four years ago when its top works were burned, and No. 4 has been abandoned and filled up many years. No. 3½, located about 300 feet east of the railway station at Huntsville, is an old mine, but still a good producer. All these mines operate on the same bed of coal, which has everywhere about the same thickness, about four feet, and the same character. The shafts are all double hoists and equipped with steam machinery. The mines most extensively operated at the present time in the vicinity of Huntsville are those operated by Caffrey and Baker. In character, the workings are drifts and all are located about half a mile west of town. They are connected with the railroad by a switch over which the company operates its own engine.

The following section from one of the mines at Huntsville is a fair representation of the Bevier bed in that vicinity :

XXVII. From Winslow.

Detail of Bevier Coal bed at Huntsville.

	Feet.	Inches.
1. Shale, drab	25	
2. Shale, black	8	
3. Coal	3	
4. Clay or shale parting		2-4
5. Coal		10
6. Clay		6-8
7. Limestone		

Another group of important mines is in the vicinity of Higbee.

The shaft of the Higbee Coal Company is half a mile west of town. The bed is about three and one-half feet thick with a thin clay parting about six inches from the bottom. The coal is of about the same quality as at Huntsville, and is used for steam generating purposes.

The following is a detailed section of the coal bed here:

XXVIII. From Winslow.

Details of Bevier coal bed at Higbee.

	Feet.	Inches.
1. Shale	80	
2. Coal		33-36
3. Clay parting		1-2
4. Coal		6
5. Clay		8
6. Limestone		

The McDonald shaft of the Inter-State Coal Company is situated two miles south of Higbee. The same bed of coal is worked here as at the Higbee shaft. The section is the same as at Huntsville, excepting that the top coal reaches a thickness in some places of forty-two inches. It varies from thirty to forty-two inches of top coal, and from eight to ten inches of bottom coal. These two mines are the only important producers in this part of the area. They are both well equipped with machinery and are valuable pieces of property.

In Tp. 54 N., R. XVI W., Sec. 31, a number of openings have been made on a coal bed which has been correlated with

the Bevier bed. There is one shaft and several small drifts. In a drift on the land of Asa Gunn, Winslow measured the following section:

Section XXIX.

Details of coal bed at the Asa Gunn drift.

	Feet.	Inches.
1. Shale	15-20	
2. Coal		30
3. Shale		18-24
4. Coal		18-24
5. Clay		
6. Limestone		

About half a mile south of this on the railroad are two abandoned shafts in which the same coal bed was worked and the detailed section of the bed was the same. This coal is worked in many small banks in other places in the area, but they are of no commercial importance. Most of these localities have been described in the preceding pages. It is unnecessary to say any more of them.

CLAY DEPOSITS.*

Randolph county is destined to become an important clay manufacturing center. Its clay deposits are extensive and valuable. Its coal deposits make fuel cheap and its transportation facilities are already good. The clay deposits of the county consist of clay shales, under clay, drift clay, loess and alluvium including gumbo.

Shales. The most extensive shale bed within the area of the Huntsville sheet is the one immediately overlying the Bevier coal bed. Its thickness varies from 15 to 30 feet. It consists usually of two phases, an upper sandy phase and a lower fine grained or plastic phase. It is shown in all the sections of the rocks associated with the Bevier coal bed and is described and its thickness noted in many sections in this report. Over a large area including the greater part of the sheet and extending into surrounding areas it lies just above drainage level making its mining easy and cheap. A sample

*The technical data for this part of the report were furnished by Mr. H. A Wheeler of St. Louis.

from this bed at the Stuart and Robinson mine at Huntsville was collected by Wheeler and gave the following tests: Color variable, mainly a light yellow to gray to brown. Texture, coarsely lammellar, hard and fine to coarse-grained. Taste, lean and very sandy. Slacks slowly into coarse flakes and granules. Pyrite is not noticeable but sand is very abundant in some places. It does not effervesce in hydrochloric acid. When ground to 20 mesh and united with 19 per cent of water it made a somewhat lean paste that shrank 5.5 per cent in drying and 65 per cent on vitrifying, giving a total shrinkage of 12 per cent. The air dried mud had an average tensile strength of 99, and a maximum of 122 lbs. to the square inch. Incipient vitrification occurs at 1,800, complete at 1,950 and it is viscous above 2,109 degrees F. It dried rapidly and heated without cracking and burned to a compact, tough body of fine red color. It is an excellent terra cotta clay and probably would make a good paving brick and a chemical analysis gave:

	Per cent.
Silica	56 86
Alumina	17.97
Water	6.96
Moisture	2.45
Iron sesquioxide	9.85
Lime	1.67
Magnesia	1.12
Alkalies	2.61
Total	98.99

Total fluxing impurities 14.75%, specific gravity 2.45. Another bed of shale equally good as this one lies beneath the "bottom rock" of the Bevier coal bed. Its value is lessened on account of its occurrence over a large part of the area beneath drainage level making it necessary to win it from shafts and also to supply artificial drainage. A sample from an outcrop a mile and a half northwest of Huntsville was collected by Wheeler and gave the following results when tested: Color, gray to olive (dry) and heavily stained yellow to brown by iron. When wet, dark gray to blue. Texture, lammellar, soft, rather fine grained and uniform. Taste fat and slightly sandy. Slacks readily to flakes and granules of small size. Pyrite was not noticeable and hydrochloric acid caused no

effervesence. When ground to 20 mesh and mixed with 21 per cent of water it made a plastic paste which shrank 7.8 per cent in drying and 5.8 per cent when vitrified, giving a total shrinkage of 13.6 per cent. The air-dried mud had an average tensile strength of 168 and a maximum of 180 pounds to the square inch. Incipient vitrification occurred at 1,700°, complete, at 1,850° and the mass became viscous at 1,950 degrees F.

It burned to a compact, tough, red body when vitrified. It dried rapidly without checking but required to be heated rather slowly to avoid cracking. It is suitable for terra cotta, paving brick and sewer pipe.

A chemical analysis gave:

	Per cent.
Silica	58.42
Alumina	25.36
Combined water	5.74
Moisture	1.41
Iron sesquioxide	6.61
Lime	1.12
Magnesia	1.67
Alkalies	2.97
Total	100.51
Total fluxing impurities	9.58
Specific gravity	2.15

Shale beds, which seem to belong to the Moberly sandstone series are extensively used at Moberly in the manufacture of paving brick, for which they are well adapted. The same series of rocks extends into the area of the Huntsville sheet, but the shales have never been used. Wheeler calls attention to an outcrop of rather sandy shales belonging to this formation in the bluff of Sweet Spring creek, three miles south of Huntsville. No sample was collected nor tests made.

Under Clays. To this class belong the beds of so-called fire-clay underlying the coal beds. None of them has ever been used in the manufacture of clay goods, though they could be used in the manufacture of earthenware, drain tile and probably paving brick. Their percentage of fluxes is too great for a fire clay. There are three beds of this clay, each about two feet thick, that lie above the drainage level over most of the area. They are associated with the three beds of

coal. The lower bed, that associated with the Bevier coal, could be mined very cheaply along with the coal.

Drift Clays. All the uplands of the area have a surface layer of drift clay reaching a maximum thickness in some cases of fifty feet. It is presumably waterlaid drift, since it is of rather uniform texture and carries very little coarse material. Such that occur with it is thoroughly waterworn. The clay is stiff, yellowish to bluish in color and very tenacious. It is used locally for the manufacture of common brick. It contains a considerable percentage of fluxing impurities.

Loess. Typical loess occurs only in the southwestern part of the quadrangle. It apparently graduates northward into the drift clays. The clay used at Armstrong for brick making is a very slightly modified loess. In the valleys west of Armstrong it becomes typical and reaches a thickness of more than 40 feet.

Alluvium. The only alluvial deposit that is of value in clay manufacture is the older phase of river and creek alluvium or gumbo. It occurs in all the larger creek valleys underlying the surface of the greater part of the floodplains. It is a dark tenacious clay of fine grain and comparatively even texture. It is used for the manufacture of railway ballast.

ROAD MATERIAL.

The deposits of the district which can be used for road-making are the beds of limestone and gumbo clay.

The limestone beds just above the Summit coal bed could be utilized for this purpose to great advantage. The beds are thick enough to furnish a considerable amount of material at small expense for quarrying. It usually occurs in thin, irregular beds, making the expense for breaking it rather light. It is a fine grained, compact limestone and would wear well on ordinary light traffic roads. These beds outcrop in every ravine across the southern part of the quadrangle, south of Sweet Spring creek and also in the northeastern corner on Sugar creek.

The use of burned clay (gumbo) as a road material is yet in rather an experimental stage yet there is little doubt that it

could be used on county roads where the traffic is light. Should its use for this purpose ever become general the great bed of gumbo in the floodplains of the streams of Randolph county would be an important source of this material.

SAND.

Sand for building purposes is now obtained from the drift deposits of the region. The supply is not inexhaustible but it is sufficient for local purposes. In the northern part of the sheet especially, the supply is considerable. It generally lies near the base of the drift deposits and in the eastern and southeastern parts is buried beneath the drift clays. Local masons report that it is a good building sand.

The sandstones of the region carry a large amount of quartz sand. Its use, however, would require crushing and probably washing.

LIME.

Lime is not manufactured anywhere in the region. The limestones above the Summit coal bed would burn into a dark lime that could be used for inside walls, though it is not probable that they will be utilized for the purpose. The Lower Carboniferous rocks outcropping within a short distance are much better for the purpose and the supply is unlimited.

INDUSTRIES.

AGRICULTURE.

The soils of the greater part of the area are fertile and easily tilled. Agriculture is therefore the important industry. It is carried on along several lines, the principal of which are stock-raising, stock-feeding and grain-growing. These branches are somewhat localized, depending upon the character of the soil in different parts of the area. The flat uplands constituting parts of the "grand divide" which are in the area are the grass-growing and stock-raising areas. The farms are large and the population is scant. The land is used for grazing and grass growing purposes and very little grain is grown. The

grain-growing and stock-feeding areas lie in the western part of the district. The farms are smaller, the population denser and schools and churches more numerous. In the southwestern corner of the area in the vicinity of Roanoake and Armstrong where the soil is loess-like are located many comfortable homesteads. The staples of the area are wheat, corn, cattle and hogs. These constitute the surplus agricultural products. They are the money products of the land. Gardening and fruit-growing, as an occupation, is almost unknown. Every farmer grows his own vegetables and fruit but no attempt is made to go further along those lines.

MINING.

The mining industry is developed in two small areas within the sheet already referred to. Near these are Huntsville and Higbee. Mining as an occupation is not pursued at any other place within the area. There are a great number of small coal mines scattered over the area but they are worked intermittently. There are about 600 men within the area who depend upon mining for their support.

Taking the whole of the three counties of which our area is a part the value of the products from the mining industries for the year 1891* were about $300,000 while from the same area the surplus agricultural products amounted to $2,300,000 in value. The former being only about 11½ per cent of the total of the two, but from Randolph county, the only one of the three in which mining is carried on on a commercial scale, the value of the products of the mines was about 37 per cent of the whole surplus products.

These figures represent shipments, and are therefore surplus. It is not possible to state whether a greater proportion of the agricultural products than of the mine products were consumed at home.

CLAY.

The clay industry of Randolph county is of considerable importance, but that of the area of the Huntsville sheet is

*Report State Labor Commissioner for the year 1891.

small. The greater part of the industry is located at Moberly. The industry of the Huntsville sheet consists of the manufacture of building brick at Huntsville, Higbee and Armstrong for local use, and the burning of gumbo at Clifton for railway ballast. The brickyards are operated by only a few men and intermittently. They use the local surface clay, drift clay at Huntsville and Higbee, and loess at Armstrong.

The burning of gumbo has been an important industry in the county during the last year or two. The product in 1892 amounted to 150,000 cubic yards of ballast, having a total value of $75,000.

ROADS.

Local communication is effected over the roads which over most of the area follow the land lines without reference to the relief, that not being of a sufficiently pronounced character to divert them. In parts of the sheet near the streams as may be seen from the map, a few of the roads follow the ridges. In the early history of the area the roads took the shortest route between the widely separated towns, so far as this could be done conveniently, and no attention was paid to land lines. They followed the ridges in general, only descending to the valleys to cross them, climbing at once to the ridge again. One of these old roads is still open and follows very nearly its old course across the sheet. This is the Huntsville-Glasgow road, the trunk line over which the products of the region passed during the days of steamboating on the Missouri river. Glasgow was the shipping point for this and a larger area north of it. The road runs from Huntsville, southwestward, through Mt. Airy, Roanoake and Armstrong.

The roads are built of the ordinary drift clays of the region. When they are graded so that good drainage is effected they are fairly good during the greater part of the year. It is only during the spring rains that they become impassable or nearly so. Where they are not graded, however, as is often the case, especially on the less frequently traveled lines they become, for some time during the late winter and spring months, practically impassable.

Road making material other than the clays are not abundant in the area and little attempt has been made to improve them or at least to build solid road beds. It is entirely too expensive to be done under psesent conditions. They are used for little else than to haul the surplus products of the farms to market. Fortunately during harvesting time they are in fairly good condition and when they are muddy during the spring months the farmer is engaged at home and has little use for them.

RAILROADS.

Three railway lines traverse the area; the Wabash, the Chicago and Alton and the Missouri, Kansas and Texas.

The Wabash railroad traverses the northern part of the quadrangle from east to west following the ridge from where it enters the sheet to where it descends to cross East Fork. It crosses the ridge west of this stream but descends immediately to Muncas creek valley which it follows to the western line of the sheet. It is part of the main line ot this system between St. Louis and eastern points and Kansas City.

The Chicago and Alton railway crosses the southern part of the area following the Higbee-Roanoake ridge to Armstrong where it begins to descend to the Missouri river which it crosses at Glasgow ten miles beyond. It is part of the main line between Chicago and St. Louis on the east and Kansas City on the west.

The Missouri, Kansas and Texas railroad crosses the southwestern corner of the area. From Moberly to Higbee it follows the "Grand divide." At the latter point it begins its decent to the Missouri river, which it crosses at Boonville. It is part of the main line of this road from Hannibal, Missouri, to points in Kansas, Indian Territory and Texas. It has a line into St. Louis also, which leaves this line at the Missouri river bridge.

TOWNS.

The towns were located originally for the convenience of the agricultural population and depended upon it then, as most of them do now, for their support. They grew up and around the solitary store and tavern of some early pioneer who set up his establishment on the line of some important road. The location of a county seat often depended upon the gift to the county of a small tract of land by some farmer upon which to build a court house, and the town slowly grew up around it. Thus it is stated the location of Huntsville was determined. They were all nurtured, whatever may have influenced their location, until quite recent years entirely by the agricultural industries. Lately the development of mining has caused an increase in the size of some of these towns, and this industry has contributed to their support.

Huntsville has a population of 1,836, according to the census of 1890. Its people are engaged in mercantile, mining and agricultural pursuits, with a few persons engaged in manufacturing. It has one steam flouring mill, a small gas manufacturing plant and small establishments for manufacturing brick for local use.

Several years ago it was quite an important tobacco manufacturing center, but it is now abandoned. The most important mines in this part of the county are located near it.

Higbee with a population of about 1,500 is supported principally by the mines in its vicinity. About 250 miners, including men and boys, are employed when the mines are in operation. The rest of its population is engaged in mercantile and agricultural pursuits. The town was commenced about the time of the building of the Missouri, Kansas and Texas railroad through the county. Until the coal mines began operations it was very little more than a railway station.

Armstrong has a population of about 500 souls. It has been built since the building of the Chicago and Alton railroad about fifteen years ago. It is a trading point for a rich

and well developed agricultural region. It has a small steam flouring mill, but no other manufacturing concerns. It has the trade of the wealthiest agricultural district within the area.

Roanoake, before the building of the Chicago and Alton railroad held the place which Armstrong now occupies in the traffic of the area. It is only a few miles from Armstrong and is nearer the center of the area from which Armstrong derives its prosperity than that town itself. It illustrates very forcibly the sad fate of a small town which is so unfortunate as to be near but not on the line of a railroad built since the town was located. Its population consists of a few farmers a proportionately large number of negroes and half a dozen merchants.

Clifton is a railroad station and a small trading point for an agricultural district.

Yates is a railway station containing a general store and postoffice.

Mt. Airy is a country postoffice.

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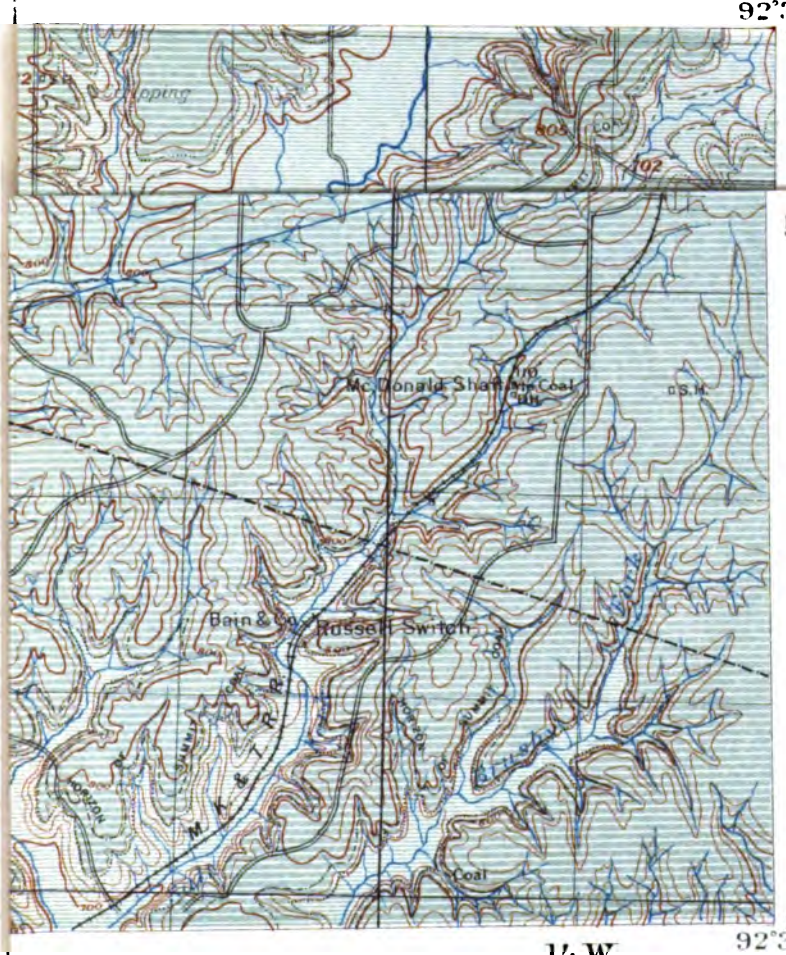
HUNTSVILLE SHEET



CONVENTIONAL MARKS

⊗ Shaft	⌒ Geological Boundary	S.H. School House
• D.H. Churn Drill Hole	▫ Building	Sh Shale
L.S. Limestone	Ch Church	S.S. Sandstone

GEOLOGICAL SURVEY OF MISSOURI,

CHARLES R. KEYES, STATE GEOLOGIST.

VOL. XII—PART III.

REPORTS ON

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BY

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GEOLOGY OF BOONE COUNTY, MISSOURI.

BY G. C. BROADHEAD.

The floodplain, or valley along the Missouri river, or "river bottom" as commonly called, lies about 600 feet above the sea. The adjacent hills are about 160 feet higher. But little of the surface of the southern half of the county rises over 760 feet above the sea. Surveys show that the University campus is about 740 feet above the sea, and at but few places near Columbia is the elevation greater than 760. Northwardly, the rise is gradual to the watershed of the Missouri and Mississippi. This watershed lies about the northern line of Boone county and is about 880 feet above the sea at Centralia. The surface deposits on the uplands do not much exceed 40 feet in depth and include the soils, local drift, loess and glacial drift. The glacial drift with some till covers all of the northern part of the county and extends several miles south of Columbia. The loess covers the Missouri bluffs, extending out a few miles and in some places rests upon the drift. The glacial drift includes beds of clay, sand, pebbles and bowlders. Among the latter are found granite and greenstone bowlders, evidently from as far off as Lake Superior, also red quartzite from South Dakota. These deposits also include concretionary masses of limestone of the age of the drift, as is proven by their occurrence along a definite line and as distributed in the adjacent clays. Some pockets of sand occur as well as decomposed granite. Many of the pebbles and bowlders are quite regularly rounded and a few show glaciated striae. The clays are sometimes jointed with a black coating between the joints. In the foundation of the Museum a 4-inch band of this joint clay was traced for over 100 feet and extended into the adjacent clay beds. A sand bed was observed 20 feet below the surface,

occurring also in wells south of the campus and in the hill next north, also one mile north. This sand bed on the south is water bearing, but it is often too strongly impregnated with iron to be pleasant. In the tunnel extending south from the chemical building there was observed as follows:

1. Made ground.
2. 1 foot of dark soil.
3. 8 feet of joint clay, upper part dark, the lower brown; near the lower part is a bed of jointed black stained clay.
4. 3 feet of dark clay and limestone nodules.
5. 1 foot of coarse, brown sand.

The excavations on the campus of the University generally show as much as four feet of soil and subsoil, then clay, sand and pebbles with occasional bowlders.

Along the Missouri hills and attaining a thickness of probably 25 feet we find the well known loess clays, consisting chiefly of a brownish pulverulent mass of clay with a little sand which may sometimes be quite marly. Round limestone concretions are often found. On Bonne Femme creek have been found the bones of the *Elphas primi-genius* or Mammoth. This has rarely been found in Missouri but the Mastodon has been found in ten counties either in springs or marshy places or else washed out from above and deposited along the stream. In one spring in Pettis county, Mr. R. A. Blair obtained parts of eight skeletons. Along the streams there are quantities of sand and gravel. The sand useful for plastering, the cherty gravel affording an excellent material for road paving. These deposits include detritus from the chert beds of theneighboring Lower Carboniferous rocks, the sands largely leached out from the drift, although part of it may be from the sandstone of the Lower Coal Measures. Exposed sections on the banks of the Missouri show it to be of alternate layers of sand and humus with leaves, sticks and an occasional clay bed. The sand often shows cross-bedding. These different layers all indicate different periods of overflow alternating with plant growth. The Missouri river bottom is generally recent alluvium.

The total thickness of Paleozoic rocks seen in Boone county is about as follows:

	Feet.
Lower Coal Measures	175
Sandstone at top of the Lower Carboniferous	25
Loose chert probably of Keokuk age	20
Limestone of the age of the Osage series of Prof. H. S. Williams	140
Chouteau limestone	55
Calcarous sandstone—base of Chouteau	1
Devonian limestone on Missouri river	25
Magnesian limestone with some beds of sandstone—Ozark series	168

Most of the streams have cut into and some of them through the Lower Carboniferous. For ten miles out of the Missouri bluffs, the Burlington beds of the Osage series* are generally the highest rock and often descend to the bed of the streams. Further north the Coal Measures generally form the upper series although often covered by the drift.

Ozark Series. The oldest Terrane found in the county occupies the base of the Missouri bluffs, from one mile below Providence to Cedar creek and up that stream to the northern part of Township 46. It consists of beds of Magnesian limestone with intercalated chert, with some green shale and a few thin sandstone layers. Fossils are of rare occurrence. Careful search may reveal them, but thus far I have not found any, but, by tracing the series, outside of the county, south and east, we are enabled to assign it to its proper geological position. It belongs to what Prof. Swallow defined as a member of his Magnesian limestone series, and the strata along the Missouri bluffs resemble those of the 2nd Magnesian limestone, with doubtfully the first sandstone and First Magnesian represented in the upper beds. It is the Jefferson City rock from the river below to the hilltop, 175 feet. At the line of Boone and Callaway it is 163 feet thick. From thence it gently dips to the west and is below the horizon at Providence. In Cole county I have obtained a few fossils from it including a *Lingula*, two species of *Murchisonia*, a *Straparollus*, an *orthoceras*, and a *Lituite*. In the New York System the geological position of this formation, would be the calciferous sandrock. Some geologists would place it at the base of the Lower Silurian. When all of its fauna shall have been

* The Osage Series includes beds of Burlington and Keokuk Age. In Boone county, chiefly Burlington.

revealed, it may prove to be of the age of the Upper Cambrian, and it is probable that in Missouri all of our Paleozoic beds below the Saccharoidal sandstone, are of the age of the Upper Cambrian. The following section was made at the line of Boone and Callaway, on the Missouri bluffs:

1. 41 feet from the hilltop.
2. 10 feet of Burlington limestone.
3. 80 feet of Chouteau limestone.
4. 15 feet of Devonian
5. 5 feet. No rock seen.
6. 85 feet Magnesian limestone.
7. 7 feet Calcareous sandstone.
8. 45 feet Magnesian limestone.
9. 2 feet Brown sandstone.
10. 39 feet Magnesian limestone.
11. 2 feet of sandstone.
12. 19 feet of Magnesian limestone.
13. 1 foot of sandstone.
14. 13 feet of Magnesian limestone.

Total height of hills 264 feet occupied by 223 feet of Pæleozoic rocks. In the above section twelve feet of sandstone is distributed in four seams, separated by the limestone. Following the river bluffs for twenty miles west, the Magnesian limestone series descends from 163 feet to zero or about eight feet to the miles. It dips more rapidly at its extreme western outcrop, or about 20 feet in 100. Below Providence its upper part includes alternations of oolitic chert, sandstone and Magnesian limestone. These last named beds are similar to those occupying a like position in Warren county over 100 miles east.

We should next expect other Silurian rocks just above, but they are not seen. We find neither Lower nor Upper Silurian; in fact, we would have to go thirty miles east to find the Trenton.

On Cedar creek, in the southern part of Sec. 16, Tp. 46, R. II, at the Clatterbuck ford the First Magnesian limestone occurs 16 feet in thickness and resting directly on the First (Saccharoidal) sandstone. These strata may be found for three miles farther up on Cedar creek.

Devonian. At the Clatterbuck ford on Cedar creek there is exposed 55 feet of Devonian limestone resting directly upon

the First Magnesian limestone beds. The lower portion contains many well-known Devonian corals including *Acervularia*, *Davidsoni*, *Favosites alpenensis*, *Stromatopora*, etc. A specimen of *Megistocrinus latus* (Hall) was also found. At Providence there is only 25 feet thickness of Devonian. In the upper part we find *F. alpenensis*, *F. nitella*, *Stromatopora expansa* and *Loxonema robusta*. Four feet lower there is a local stratum abounding in a *Pleurotomaria* not before found and which I have described in the American Journal of Science as *P. Providencis*. Other fossils found were *Spirifer eruteines* and a cup coral. The upper beds are often minutely specked with calcite. The gasteropod fossils show a calcite and pyrite shell with an interior filling of limestone. At Providence there is 25 feet of Devonian limestone. On Cedar creek 55 feet, while on Snyder creek Callaway county there is exposed over 40 feet of shaly beds with Brachiopod fossils and overlying the limestone beds of Boone. The Subcarboniferous or Lower Carboniferous as found in Boone county includes portions of three groups, viz: Chouteau 55 feet, Burlington about 160 and probably 20 feet of Keokuk. The Chouteau occurs in the Missouri bluffs, from the east county line nearly to Huntsdale and on a few streams flowing southwardly. At Providence its lowest member consists of one foot of whitish sandstone with green partings containing the well marked *Taonurus Cauda-galli*. Above this is 50 feet of limestone the upper 20 feet consisting of thick beds of drab limestone inclosing a few silicious geodes and has but few fossils. Next below this is 3 feet of a brittle dove-colored limestone in thin layers and abounding in fossils including three or four species of *Rhynchonella*, and *Orthoceras*, several species of *Productus*, *Spirifer*, *Entolium Shumardana* and others. Next below this is 25 feet mostly in thin layers. Fossils abound in the shaly partings of the limestones including several species of Trilobites, a dozen crinoidea and many Bryozoans. Other fossils found were *Orthoceras*, *Gomphoceras*, *Goniates Gorbyi*, several species of *Spirifer*, *Orthis*, *Strophomena*, *Leptaena depressa*,

Pentremites Roemeri, *Auloporo*, *Platyostoma Broadheadi*, *Euomphalus*, many corals and several species of *Lamellibranchiata*.

Prof. James Hall in his investigations in Iowa forty years ago assigned this group to the Devonian. Prof. Swallow also, about the same time considered it to be Devonian and of the age of the Chemung of New York. The *Taonurus Cauda-galli* found here also occurs in the New York Chemung. Prof. Meek thirty years ago regarded it as of the age of Lower Carboniferous. Most of our geologists also consider it to be at the base of the Lower Carboniferous. In Illinois and Iowa it is spoken of as the Kinderhook. In Indiana and Kentucky the Knobstone group is considered its equivalent. In West Virginia and Pennsylvania the Vespertine series is of about the same age. The Marshall group of Michigan and Waverly of Ohio are also of same age. The fossils of the Chouteau in Pettis county and at Providence seem to be identical with the Waverly of Ohio. Some other fossils found in the Missouri Chouteau look very much like the Devonian. In Boone county very few of the fossils seem to be related to the overlying Burlington, and the aspect of the Chouteau fauna looks very much like the Devonian.

THE OSAGE SERIES.

This includes the Burlington and Keokuk beds. In Boone it may chiefly be referred to the Burlington. Prof. Swallow in his first survey applied the term "Encrinital" to the formation known to geologists as the Burlington, because it abounded in so many crinoidal remains, but as rocks of other ages are crinoidal it was thought best to apply the name to the group where best developed. Hence it has been called Burlington. Prof. H. S. Williams applied the name Osage Series to both Burlington and Keokuk beds as they are often difficult to separate in Missouri bluffs. At Providence it surmounts the Chouteau and reaches nearly to the hill-top with a thickness there of 80 feet. From Huntsdale to Rocheport it includes the entire rock bluff. It is also often seen between Columbia

and Providence. Its lower beds are thick and often of a buff or brown color with many white crinoid stems.

A section on Hinkson bluffs below the Jefferson City road shows as follows:

1. 25 feet of gray loosely cohering limestone.
2. 80 feet of gray limestone, some of the upper beds contain small nodules of oxide of iron generally about ¼ of an inch in diameter. (These nodules are altered from pyrite.)
3. 11 feet of shelly gray limestone with a few fossils including *Orthis Burlingtonensis, Metoptoma umbrella, Spirifer.*
4. About six inches of brown crinoidal limestone.
5. 2 feet of brownish gray limestone with many fossils including *O. Burlingtonensis, O. dubia, O. Swallowi, Prod. Burlingtonensis and Spirifer plenus.*
6. 4 ½ feet of gray limestone with *Metoptoma Umbrella, O. Burlingtonensis, O. dubia.*
7. 5 feet of soft shelly, brownish gray limestone with *Chonetes, Orthis Burlingtonensis, O. dubia, Prod. Burlingtonensis.*
8. 1 foot of shelly limestone with many fossils. *Spirifer, Orthis, Chonetes, Productus.*
9. 4 feet of soft shelly gray limestone.
10. 6 feet of soft brown and cherty limestone.
11. 5 feet of brown limestone, lower part shelly.
12. 5 feet of gray limestone in two beds.
13. 5 feet of buff limestone.
14. 2 feet of shelly gray limestone.
15. 2 feet of fine-grained buff limestone.
16. 5½ feet of shelly crinoidal gray limestone—to low water in creek.

The lower beds are more often the thicker and of a brown or buff color, the upper are thinner and generally of a gray color, or bluish gray within the quarry. Most of the beds are made up, chiefly of numerous crinoid fragments some showing the form of a stem or plate, the others merely fragmentary. The upper beds are not so coherent as the lower. The bedding planes are rough and irregular, which necessitate some dressing for building purposes.

A peculiar and frequently observed feature is the "Stylolite" structure which has been called suture-jointed from the fancied resemblance to skull sutures. Others have called them crystallites. They may be related in origin to cone-in-cone or to "slickensides" but nevertheless they preserve their own typical character throughout and in no instance can they be mistaken for any other form. Outwardly they sometimes resemble fossil wood. Sometimes a thin

coating of smooth dark clay rests on top of the stylolite. In a few instances I have seen where a stylolite has developed from beneath a fossil, the fossil forming a table top just as ice tables or mud tables are formed. This would go to prove that the stylolite was an after product to the formation of the limestone. As the limestone would harden there would be a pressure, a slipping or quivering of strata and the stylolite band would be inaugurated. This feature apparently does not injure the building qualities of the rock. Leaving out such objections as I have above named, the Burlington limestone is one of our best building stones. The old University columns, those of the Boone county court house and of the State capitol at Jefferson City, are built of it and have been in use fifty years. Time has proven its use, fitness and durability. The foundations of all the university buildings are of this rock. The foundation of the custom house building, St. Louis, is mostly of rock of this age quarried at Quincy, Illinois. It also furnishes a preeminently useful stone for burning into lime and has been so used at Hannibal, Columbia, Sedalia, Carthage, Ashgrove and Springfield. The incoherency of the upper beds has rendered them easily susceptible to erosive agencies, and to that fact do we owe the frequency of underground caves, of which there are probably a dozen in Boone county. Many sinkholes also occur, which are formed by the wearing away of the subterranean rock, which is then carried off by the streams, leaving the upper strata suspended. From being thus weakened they in time sink, and we have the funnel-shaped sinkholes. In after time these sinks become partly filled, and we have ponds which are often met with in the western part of the county, and also southeast of Rockbridge. We find at Rockbridge a cave, a large sinkhole and a rock bridge with a bold stream of water flowing through and under the bridge. Commers' cave, ten miles north of Columbia, has been long and well known. It has a wide and high entrance, becoming narrowed within a quarter of a mile. It is reported to have been explored over a mile. It is muddy within, although a clear

stream flows out. Stalactites are found, but they are of a dirty appearance.

Four miles below Rocheport there is another cave and there are several others in the Se. also in the Nw. part of the county. At Quillans, eight miles southeast of Columbia, and on the hilltop, there is a pond 100 feet in diameter. Two hundred yards south we enter a cavern, divided into several rooms, where fruit may be kept fresh all the time; descending by a series of steps for 50 feet vertically we reach a spring.

The bluffs near Columbia weather into curious and interesting columns and escarpments. On Silver creek, fifteen miles north, there is a remarkable weathered promontory called the "Pinnacle." The stream coming from the north suddenly turns west for probably 600 yards, then curves south and east for about the same distance, where it is separated from the northern bend by not over a hundred feet, it thence bears away southwardly and then to the west. Inclosed within is a peninsula, which is solid rock in its eastern one-half; this is 40 to 80 feet high, weathered into a sharp serrated ridge with barely sufficient space at top to walk upon. This sharp edge at two places is pierced by wide apertures, one of them 10 feet in diameter with 20 feet of rock above.

Overlying the Burlington there is generally found about 20 feet of broken chert and red clay. The chert often incloses well preserved silicious fossils, often beautifully crystalized and showing the structure. Some of these are apparently of Keokuk fauna.

Keokuk Group. On Silver creek I observed about fifteen feet of ash gray limestone of *Archimedes.* At one or two places we find 15 to 20 feet of a dirty, white sandstone lying on an eroded limestone. This is undoubtedly the top member of the Lower Carboniferous.

Upper Carboniferous. This only includes the lower members of the Lower Coal Measures, probably not amounting to over 200 feet in the county. At the base there is seen from ten to twenty feet of fireclay of good refractory quality. The beds above consists chiefly of shales with some limestone, a

little sandstone and about four seams of coal. The following is a vertical section seen near Columbia:

1. 7 feet of ash blue limestone.
2. 5 inches black coal smut and slate.
3. 10 feet of clay shales, blue and red, sandy.
4. 4 feet of rough nodular limestone.
5. 10 feet of shales and thin sandstone beds.
6. 2 feet of jointed limestone—weathers brown.
7. 1 foot 2 inches black and gray shales.
8. 1 foot 8 inches coal, good quality.
9. 4 feet of gray fireclay.
10. 2 feet 6 inches dove-colored limestone.
11. 9 feet of dark, smooth clay shales
12. 4 feet of sandstone.
13. 7 feet 6 inches of gritty sandy shales.
14. 9 feet of bituminous shales.
15. 3 feet of coal—30 inches to 3 feet. Has pyrite seams.
16. 30 feet, chiefly shales.
17. Outcrop of limestone
18. 38 feet to rotten coal.
19. 2 feet rotten, impure coal.
20. 16 feet 6 inches chiefly limestone.
21. 1 foot of coal.
22. Fireclay.

Condensing the above we have:

1. 85 feet coal measures.
2. 1 foot 8 inches coal.
3. 36 feet coal measures.
4. 3 feet of coal.
5. 65 feet coal measures.
6. 2 feet of rotten coal.
7. 16 feet 6 inches coal measures
8. 1 foot of clay, 10 feet fireclay.

Total of above 163 feet.

The fireclays at the base are well exposed at several places east of Columbia and may be as much as 20 feet thick. The basal measures may underlie one-fourth of the University campus and include one foot of coal. Tumbled masses of Upper Carboniferous limestone were found beneath the old University building. Other strata underlie the observatory, consisting of the limestone, overlying a few feet of shale, with coal beneath and clay still lower. At this place a chalybeate spring occurs, the water receiving most of its iron from the coal and its related shales. This coal is also repeated in the road forming the eastern extension of Broadway, at 35 feet

below the hilltop. It crops out in a ravine on the north, at foot of hill where its associated strata appear thus:

1. 8 feet of ash blue limestone close textured and containining Upper Carboniferous fossils including *Fusulina cylindrica* and *Orthomena*.
2. 1 foot 6 inches like No. 1 but layers are more even the rocks of a mottled blue and brown.
3. 2 feet of bituminous shales in thin laminæ.
4. 4 inches of brown fossiliferous shale.
5. 1 foot of coal, corresponds to No. 21 of section above.
6. Fireclay.

On Hinkson creek east side, a half mile above the water works the last named section is repeated and continued upward. The section from hilltop down is as follows:

1. 20 feet slope from top of hill.
2. Outcrop of jointed limestone.
3. 50 feet, rock are chiefly concealed, outcrop of bituminous shale near lower part.
4. 30 inches of coal.
5. 49 feet rocks concealed.
6. 5 feet of blue and brown shales.
7. 1½ inches of fibrous aragonite.
8. 5 feet of blue and brown shale with ochre concretions.
9. 3 inches of satin spar or aragonite with coating of selenite.
10. 8 feet of blue shales
11. 2 feet of rotten coal.
12. 2 feet clay with selenite crystals.
13. 4 feet of nodular limestone and clay.
14. 1½ feet of calcareous clay.
15. 3 feet of roughly bedded limestone.
16. 1 foot of calcareous clay.
17. 2 feet of limestone.
18. 3 feet of bituminous shales.
19. 1 foot of coal.
20. Fireclay in the creek.

At the lower end of the hill where the bottom part of this section was obtained, there is an apparent fault, the strata to the south of a small hollow being five feet below the corresponding strata on the north, but as it was covered with talus from above its exact character could not be seen. From this point for three hundred feet up stream, the strata rise over 12 feet, while 300 feet down stream the Lower Carboniferous rises twenty feet above the water, and a quarter of a mile up stream it again appears, as well as up a small branch on the west side of the creek with Coal Measures appearing at a higher eleva-

tion, all showing that the Coal Measures here occupy an eroded basin and have also been subsequently tilted. We would conclude that the Upper Carboniferous underlies the upper part of the hills, from near McAlesters southwardly to the University campus, but probably only includes the lower two coal seams. From this northwardly, we again find coal mined at Kurtz' about 30 inches thick, and still further north for over a mile are other drifts. On the railroad, four miles north of Columbia the coal is found three feet in thickness at over one hundred feet depth. At Keenes two miles west it is mined at 113 feet depth and is also three feet thick. Coal underlies most of the country north of Columbia. A mile east of Centralia it is reached at 70 feet depth and capped by bituminous shales. Coal is also mined near Harrisburg, and is three to four feet thick near the northwest part of the county. One mile south of Hinton, I observed :

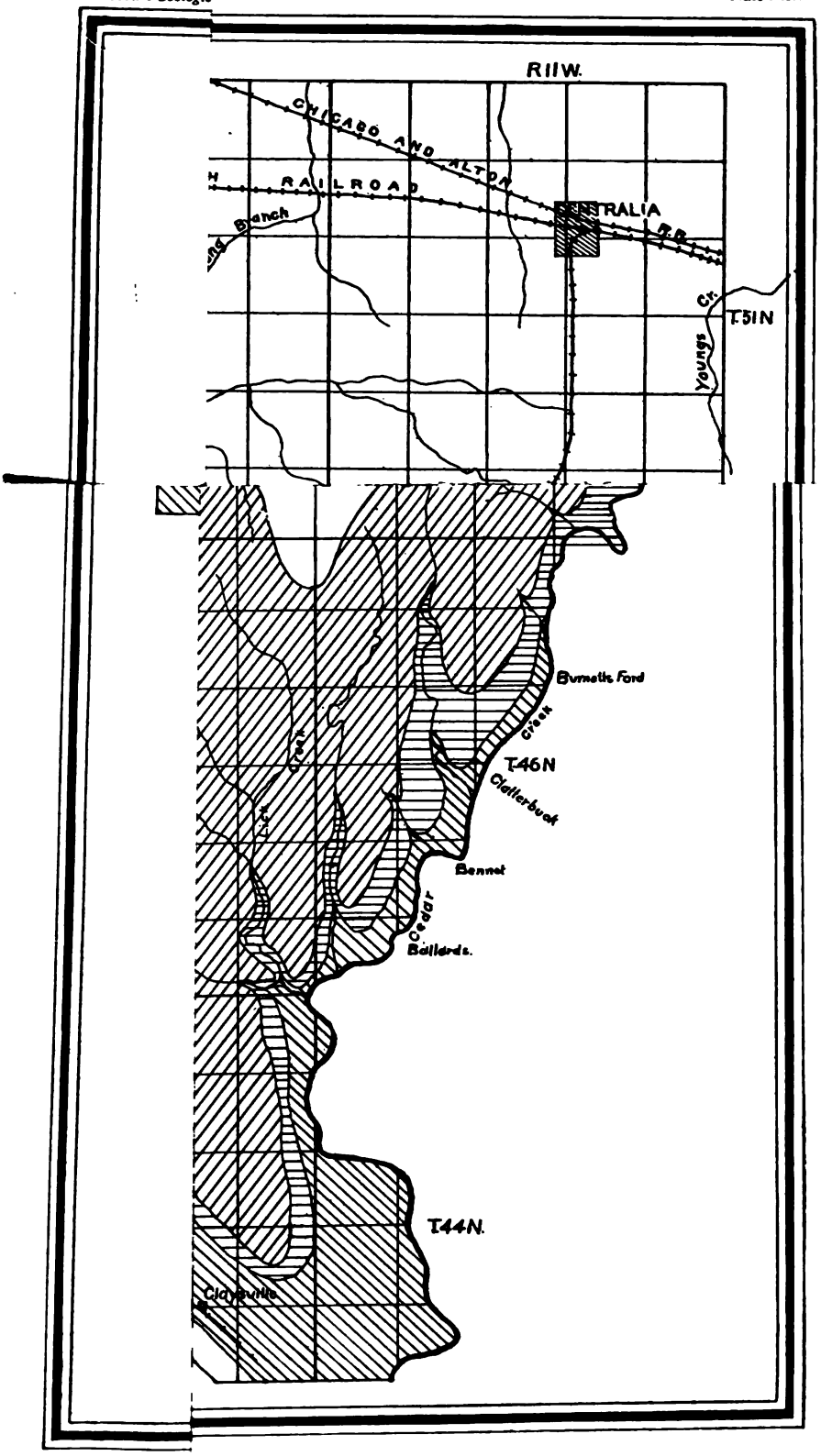
1. 2 feet of bluish and roughly bedded drab limestone.
2. 6 inches thinly laminated clay shale.
3. 4 feet of irregularly laminated olive clay shales with concretions; contains *Productus Prattenianus*.
4. 1 of deep blue shale, thin laminæ.
5. 1½ feet of argillaceous limestone, ash colored and with pot metal ring.
6. 2½ feet of jointed bituminous shales.
7. 1 foot of coal.

Several coal pockets have been observed, one of them 200 yards above the water works on east side of creek, and occupying a narrow eroded valley in Lower Carboniferous strata, not over 100 feet wide, and extending a short distance into the hill, but inclosing a bank of coal, thick enough to delude the coal miner into drifting into it. The coal mines operated northeast and higher in the hills are regular beds of coal. Another pocket has been observed three miles southeast. At this place the strata on the small branch adjacent and 100 feet lower down the branch is of the age of the Lower Carboniferous as it is also a few hundred feet up the branch. The slopes of the hills are uniform and include clays and loose chert. Digging here has revealed a small bank of coal.

Minerals. Lead and zinc sulphide have been dug up on Sec. 14, T. 46, R. 13, Missouri bluffs. The ore here is associated with calcite and occurs in the lower beds of the Burlington limestone. Sphalerite or blende occurs at several other places in the county. Small pieces have been found in the limestone within a mile of Columbia. In the coal mine on the railroad north of Columbia zinc blende occurs in the coal and incloses iron pyrites. In southwest Missouri this ore of zinc is seen coated with pyrite or marcasite, as an after product. That may be the time relations in these specimens if so the pyrite is a replacement of sphalerite. Another, specimen from the same mine shows fractured coal with plates of crystallized baryte inclosing sphalerite. Other pieces of coal from this same place show calcite and pyrite in the joints of the coal, also flattened tree trunks pyritized. The Chouteau rocks at Providence often inclose particles of pyrite. The Devonian at the same place shows that the shell has been replaced by calcite with a thin coat of pyrite both within and without. Fossils in the chert layers, of the upper part of the Lower Carboniferous, often have their interior of drusy crystalized quartz, which sometimes preserved the shell structure very beautifully. Large chunks of silicified wood are often found, showing small quartz crystals. The coal shales, in the lower part of the Upper Carboniferous, inclose two beds of fibrous aragonite or satin spar. At the same place there are also found nice crystals of selenite. In the burning heaps of clay shales, thrown out from the coal mines, acicular crystals of sulphur are often found. These shales also, although quite soft and subject to decomposition from exposure to water, when burned, become as hard as the hardest brick, and of a brick-red color, and very close cryptocrystalline structure. They also thus become very durable and are much used for walks. Some specimens show crystals of white silky hairlike form, which Mr. Lockwood determined to be Alunogen.

In the coal shales, flattened ochre concretions often occur. In the Upper Limestone, near Columbia, we find round nod-

ules of limonite which investigation has proven to be pseudomorph after pyrite, in fact the successive changes from pyrite to limonite have been observed. Masses of red hematite are occasionally found, some weighing over fifty pounds. A piece as large was found three miles north of Columbia. Other masses have been found near Ashland, and in the southern part of Callaway county deposits of this ore have been found. Its exact geological position is not known, but it is supposed to be of the age of the Lower Carboniferous.


R11W.
CHICAGO AND ALTON
RAILROAD
Branch
CENTRALIA
T.51N
Ct.
Youngs
Burnetts Ford
Creek
Creek
T.46N
Clatterbuck
Bennet
Cedar
Ballards.
T.44N.
Claysville

THE OZARK UPLIFT AND GROWTH

OF THE

MISSOURI PALEOZOIC.

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THE OZARKS.

Long, in his expedition to the Rocky Mountains, published in 1823, mentions the "Ozark Mountains" as a hilly region not entirely entitled to the name of mountains. Schoolcraft visited southern Missouri and Arkansas in 1819, 1820 and 1823, and wrote a volume entitled "A Visit to the Semi-Alpine Region of the Ozark Mountains."

In no previously published book do we find any mention of the word Ozark, nor do we find any definition of the term. The names of most of our rivers were given to them by the early French. Ozark may be of French origin, if so it would have been spelled differently at first and afterwards anglicized or spelled in a corrupted English form. It may have been "Aux Arcs," meaning "to the bow," or at the bow, or towards or in the hills where good timber for bows may be found.

But, although the geology of the Ozarks has been often discussed, it remained for myself first to discuss its geological history in an article read before the American Association for the Advancement of Science in 1888 and published in the American Geologist for January, 1889. In that article I spoke of the entire region of the Ozarks as the "Ozark Plateau," and the effort of forming it as the Ozark uplift. In the American Geologist for July, 1891, and December, 1894, I used the term Ozark series to include Swallow's entire magnesian limestone series, extending over 30,000 square miles of area in Missouri. That name seems to be eminently appropriate as it includes rocks chiefly found and better developed within the Ozark plateau, and now all geologists who write on Missouri geology

use the term "Ozark," thus recognizing its eminent fitness. I was thus the first person to speak of the Ozark plateau, also to give name to the Ozark series and to discuss the Ozark uplift. Since then other geologists have entered upon the discussion.

According to the census of 1890 the area of the State of of Missouri is 69,415 square miles. It includes the Swamp region, the Ozark Plateau, and the Prairie plains. The Swamp region aggregates about 3,000 square miles in the Southeast.

The Ozark plateau includes about 30,000 square miles in Missouri. It is bounded on the north by the Missouri, on the east by the Mississippi and the Southeast Swamp region and on the west by the southern extension of the Prairie plains and is limited by a line passing southwesterly from near Glasgow via Marshall, Sedalia, Stockton and Peirce City. Its exact boundary cannot be defined but it is approximately as I have stated. On the south it extends into Arkansas and probably nearly to the Arkansas river. On the east the Ozarks are 700 to 800 feet above tide, on the north 800 to 1,000, on the west 850 to 1,100 and 1,500 feet in the southwest.

In Missouri the Ozark plateau is over 200 miles wide east and west and over 150 north and south and consists of an elevated table land cut into by various stream channels, those on the north flowing to the Missouri, those on the South chiefly to the Arkansas, those on the east to the Mississippi. While many of the tributaries of the Missouri head one-half or more of the distance to the Arkansas line we have only one stream in Missouri, the Merramec, of any great length that flows into the Mississippi. All the others in eastern Missouri head less than 20 miles from the river.

The elevation of the higher land within the Ozark area varies from 1,200 to 1,800 feet above the sea, the highest known being in Iron and Wright counties.

The prairie plains of the north, northwest and west, are of less height, being about 800 feet in Montgomery, 850 in the northern part of Boone, 1,000 in Schuyler and 1,200 in Nodaway county. As the elevation of the Ozark plateau has been due to a great quaquaversal movement upward, it would in

this process, although the movement may have been slow and continued during a long period of time, tend to fracture the strata in many places. Within this area but few fractures have been observed that could be clearly traced to this cause, yet this may have been the cause that has produced some of our stream channels to be subsequently erodod. Evidence goes to show that the origin of many earthquakes is not far below the surface and records show that miners may sometimes be at work below the strata affected by an earthquake. The effect of the Ozark uplift may be observed at several places along and from its margin. At Hermann, and near Portland and Bluffton are slight faults and local inclines. At Hermann the rocks of the river bluff are faulted leaving the opened space filled with tumbled rock from the adjacent strata. One mile south of Fredericktown the road crosses tilted beds of limestone for several hundred feet. A similar dip of strata has been observed on Marble creek, Iron county, and the marble beds which lie near the base of the Ozark series in Iron and Madison, generally lie at an angle of 15° to 20° with the horizon. At Grand Chain on the Mississippi the Trenton is elevated and forms a reef extending across the river from which place the axis extends eastwardly to the Ohio in Pulaski county, where another reef has been observed a few miles above Caledonia. (See Vol. I, Geology of Illinois.)

Prof. Worthen in 5th Vol. Illinois Geological Survey, speaks of a remarkable disturbance in the northern part of Monroe county where the Coal Measures are seen resting unconformably on the upturned beds of the Lower Carboniferous, showing that there was a disturbance of strata, which took place subsequent to the laying down of the chester beds and prior to the era of the coal. Another well defined axis crosses the Mississippi at Plattin rock and upturns the First sandstone exposing about 50 feet thickness at Crystal City, Missouri. The strike of this passes along a monoclinal east of the line of Franklin and St. Louis county, Missouri, thence to Augusta, St. Charles county and northwardly causing the Trenton limestone to appear on Dardenne creek, with Lower

Carboniferous east and west, next on Peruque creek near Forestell where the Devonian is seen for a short distance. On Cuivre river, Lincoln county, older strata appear flanked by other more recent. A continuation of the Ozark uplift may be included in a certain swelling up of older strata near Auburn, Lincoln county, Prairieville, Pike county, and northwestwardly near Frankfort, New London and lastly at Newark, Knox county, where the Chonteau limestone is seen surrounded by Burlington outcrops. From Bennett's landing on the Mississippi to Shawneetown on the Ohio, there is a range of hills 500 to 600 feet above the river at Cairo, to which the name Shawnee mountains has been applied. The Cap Au Gres axis may be an offshoot from the Ozarks. At Westpoint, Illinois, it brings up 75 feet of Saccharoidal sandstone to view for probably a mile along the Mississippi with the First Magnesian limestone overlying it. Just up stream across a small branch, the First Magnesian is the lowest rock seen, thus indicating a fault. West of this and in the bluffs north of Winfield, the Second Magnesian limestone is seen at the foot of the bluffs and on the south side of Sandy creek the Burlington limestone is tilted up 80° and within a short distance south the St. Louis limestone is seen occupying a horizontal position. Northwest of this the Cap Au Gres axis can be traced for several miles, by a succession of sinkholes.

In southern Missouri the Mississippi is apparently along or near the axis of a monoclinal. The Carboniferous appears at several places along its bluffs in southeast Missouri, but as we recede westwardly older rocks soon appear and at a higher elevation. Across the Mississippi in Illinois the rocks are of more recent age and occupy a lower geographic position. The Missouri river also as far up as Howard county is similarly situated, being at or near the break off northwardly of the monoclinal. The dip of strata at some places really begins several miles south of the Missouri. The monoclinal axis on the north of the Ozarks also seems to be quite irregular in strike. Furthermore the corresponding strata on the north side of the Missouri are lower than those on the south side.

From Augusta to within three miles of St. Charles there is a downthrow of 800 feet. The Ozark series and superincumbent rocks lie in a horizontal position at and west of Augusta. At St. Charles the St. Louis limestone is horizontal. Most of the intermediate formations are found between these places. Within one mile east of Augusta two hundred feet of strata pass below and out of sight. From St. Charles county to Boone the series are nearly horizontal. At the line of Boone and Callaway 160 feet of Second Magnesian limestone is seen. One mile below Providence these beds have dipped west out of sight. A few miles above Providence the Chouteau limestone disappears and as far as Glasgow only the Lower Carboniferous beds appear. These are last seen at Miami. Farther west and northwest in Missouri we only find strata of the age of the Upper Carboniferous. Half way between Glasgow and Boonville, the Chouteau rises in the bluffs by a gentle swell, and across the river in Saline county other rocks of older age are seen, and a few miles east of Marshall the Chouteau again appears in sight, but is not again seen until we approach Sedalia. On the west flank of the Ozarks either the Chouteau or Burlington rest upon the Ozark series and in going west we soon find rocks of the Upper Carboniferous. A boring at the Insane Asylum, St. Louis, shows that the Saccharoidal sandstone was reached at a depth of 1,452 feet. Forty miles south of Crystal City, fifty feet of this sandstone appears at the surface and forty miles west of St. Louis, at Augusta, it is at the surface. At Westpoint, Illinois, fifty miles northwest of St. Louis, it is again seen at the surface. From Crystal City, via Pacific to Augusta, it is almost continuous, occupying part of the rim of a basin or trough, whose inner part or bottom at St. Louis is 1,450 feet below the surface. From Augusta to Westpoint, after passing over one-third the distance, the rocks are Lower Carboniferous and if the concealed strata are as thick as seen on the Missouri west of St. Charles, our sandstone sinks about as much as five hundred and sixty feet below the surface, to rise again to the surface at Westpoint, Illinois. From this it

would seem that there is a broad synclinal or trough, extending in a northwest direction from St. Louis, through the middle of St. Charles county, and indefinitely northwestwardly. Eastwardly the equivalent of this formation is not seen until we reach the Appalachians.

THICKNESS OF PALEOZOIC.

In southeast Missouri, the Paleozoic rocks rest upon the Archæan porpyries and granites, the porphyry hills often rising several hundred feet above the Paleozoic beds. The Archæan rocks are well exposed in the counties of Iron, Wayne, Madison, St. Francois and Reynolds and are sometimes traversed by dykes of basic rocks. It has been reported that borings in Jackson county extended to 2,500 feet into granite or schist. At the Insane Asylum, St. Louis, the Paleozoic rocks were passed through between 3,500 and 3,800 feet. Measurements in northwest Missouri along the Missouri river show nearly 2,000 feet of Upper Carboniferous. The boring at the Insane Asylum included not much over 100 feet of Coal Measures. Add these borings to Upper Carboniferous of the northwest and we have 5,500 feet. The Jackson county boring may include 850 feet of Upper Carboniferous. Subtract this from 2,000 (total Upper Carboniferous) and add to 2,500 and we have 4,600 feet in northwest Missouri through which to reach the Archæan floor. Averaging this with the first figures and we have 4,575 feet of Paleozoic rocks in Missouri. This I consider to be about the proper average thickness.

At the close of Archæan time Missouri was occupied by a deep sea, the Cambrian sea, with Archæan islands of granite and porphyry. The erosion during Archæan time must have been great everywhere, as much in Missouri as elsewhere. The broken and ground-up material was needed in order to build up the succeeding Cambrian, and those early Cambrian seas may have been several thousand feet deep, extending from Texas to Lake Superior with Archæan islands in Burnett county, Texas, and southeast Missouri. If the early Cambrian was ever formed in Missouri, it must have been eroded to give

place to the later formed Upper Cambrian. It was either this, or else there was dry land on the Archæan Ozarks until the time of the Upper Cambrian, when the sea subsided sufficiently to receive it. The Archæan floor of the Ozarks was certainly very irregular, with deep valleys and tall peaks, the higher in Iron counties with lesser elevations in Madison, Wayne, Reynolds, Carter and Shannon. In southeast Missouri, the evidence snows that the first formed rock was a shore deposit. This, a sandstone, sometimes containing large rounded bowlders of older rocks, at other times fine grained, rests upon Archæan rocks in the counties of Madison and Iron.

THE OZARK UPLIFT.

The chief rocks of the Ozark plateau include a series of Magnesian limestones and sandstones amounting to one thousand feet in thickness. In 1891 I applied to these rocks the name "Ozark Series." The lower one-half to two-thirds may be Cambrian, including rocks of the age of the Potsdam of New York. The upper portion may be the equivalent of Dana's Canadian, or the lower part of the Lower Silurian. The evidence shows that the life of the Cambrian sea in Missouri was limited to but a few species. We find a few *Orthoceratа*, a *Lituite*, a small *Orthis*, a *Pleurotomaria*, a *Maclurea*, two species of *Ophileta*, two or three species of *Straparollus*, probably two species of *Murchisonia*, an Obolella, three or four species of Trilobites, while in the Potsdam of Wisconsin and Minnesota several other Trilobites may be found. Where the waters were shallow sea worms lived and left their track in irregular windings in the rocks. In the later seas sea weeds abounded, as shown by certain beds of the Second Magnesian limestone. That the Ozark series was subject to erosions and slight elevations and depressions, is shown by the occasional appearance of a few feet of sandstone at intervals of a few feet to over a hundred. Near the close of the Ozark terrane it is probable that a large area of the plateau was elevated above water. This effort was doubtless quaquaversal and affected the entire plateau. But at the same time great erosion still progressed,

the material being carried away by the currents to form other later-made rocks. The sea probably still extended to the Wisconsin highlands and eastwardly. In this sea the Silurian and Devonian beds were laid down, but thus far no residual deposits or terranes above the Ozark series and below the Carboniferous have been found upon the Ozarks, nor have they been found in place resting upon the west flank of the Ozarks, nor have there any such deposits been found on the eastern flank of the Ozarks, after passing a few miles west of the Mississippi. This looks very much as if the Ozark plateau was dry land during Silurian and Devonian time.

THE CARBONIFEROUS.

The subcarboniferous seas in Missouri abounded in *crinoideæ*, *Mollusca* and the rocks indicate only moderately deep seas and it is probable that at least the western one-half of the Ozarks may have been submerged during this time, for beds of the Chouteau limestone have been found on the higher Ozarks at 1,650 feet above the sea in Wright county, and 1,000 in Maries, and Burlington limestone on the highlands of Morgan, Benton and Hickory. In western Missouri the Ozarks are flanked everywhere with lower Carboniferous limestone. From these facts it would appear that the Lower Carboniferous seas at one time may have rested upon a large area of the Ozarks, forming beds of rock, which later have been nearly all swept away.

The accumulation of sediments in the Carboniferous seas of the Mississippi Valley, seems to have been greatest along the Mississippi trough and are chiefly limestone. The lower groups are represented by thick beds of limestone in north central and southwest Missouri. The upper portions are only represented by residual deposits in the southwest. At the close of the Lower Carboniferous, there was a marked change in fauna and flora, as well as continental area. The deep ocean floor, east, west and north of the Ozarks, which had been so long receiving marine deposits, soon began to rise, forming a gently undulating land surface, over which were lakes and vast

swamps, beginning to support a rare and luxuriant vegetable growth; the forerunner of the coal period. The leaves and older trees fell, and accumulated in the peaty swamps, and were in time covered by sediments from rivers or inflowing seas. Soils were thus formed, forests grew and matured and lycopods and ferns left their debris to be again covered up. At one time the surface would subside so much that the inflowing seas would leave a thick calcareous deposit, which later would harden to limestone. In this way by elevation, repose, subsidence, and re-elevation, the process would go on, and the record would show a number of ancient forests and ancient soils and coal beds of different thickness, proportioned to the forest growth. The process continued until there was accumulated at least from 700 to 2,000 feet of Upper Carboniferous in northeast Missouri. There may have been several thousand feet thickness formed, but during long succeeding ages a great part was eroded and borne away. Certain patches or pockets of coal have been found high in the Ozarks, at 1,000 feet above the sea. This would indicate that the Upper Carboniferous, or its lower beds, may at one time have rested upon part of the Ozarks. Such evidence has been reported from Crawford, Cole, Osage, and probably Howell. As far as I know no limestone beds have been found at these places to indicate Carboniferous age, and these deposits are also remarkably free from fossils. With these exceptions, no other rocks of the age of the Upper Carboniferous have been found in southeast Missouri excepting in St. Louis county, and at a few places in the Mississippi bluffs in the lower southeast. Around the margin of the lower coal measures, where they rest upon rocks of older age, are found isolated coal deposits consisting for the most part of impure bituminous or cannel coal. These coals may be a few feet, or as much as twenty or fifty feet or more thick and are often tilted from a horizontal position. In some places the tilting may result from local causes, such as washing out and settling of the adjacent older strata. These coals generally occupy side valleys tributary to larger valleys, and the adjacent rocks to the hilltop, are of older age than the

coal. These coal basins also are rarely more than two hundred feet in horizontal extent. In north Missouri the coal pockets rest upon the Lower Carboniferous. In Cole county, and westwardly and southwestwardly, they repose on rocks of the Ozark series, and in no instance have I observed them occupying eroded valleys of the Upper Carboniferous. It is rare that fossils have been found associated with these deposits, but I have specimens from Lincoln county containing impressions of Sigillaria, and from near Boonville, containing Lepidodendron. Iron pyrites and zinc blende are often found, and at the Simpson mine in Moniteau county thin seams of galena occur with the coal.

During the Upper Carboniferous time, the country beyond central Kansas and extending to the Rocky Mountains, was most probably beneath the seas; for, although there are rocks of the age of the Upper Carboniferous, both in Wyoming, Colorado and New Mexico, there is found no coal of Carboniferous age in those states, but the formations all indicate deep sea origin. Only at Las Vegas, New Mexico, I have found an impression of Lepidodendron on sandstone, indicating a condition of land surface. At the close of the Paleozoic the Appalachian revolution took place, strata were crushed up, bituminous coal was changed to anthracite, and the mountains from New York to Alabama were formed. If there was any movement of the Ozarks at that time it was slight. Certain tiltings of the Coal Measures, probably local, have been observed, but they may have taken place long after that time; but the last great effort of the Ozarks was later than the Chester, and probably prior to the coal period.

GENERAL EROSION.

After the close of the Paleozoic erosion continued, and the stream channels were made deeper. At the present time it would seem that our streams had reached their base level. In north Missouri they may have been deeper than they now show, for the hills may have been worn down more than those in south Missouri.

The Missouri river shows a valley or floodplain, one to two miles wide, with an inner channel or trough; the floodplain eroded before glacial time, then filled up and still later, the inner channel has been formed to receive the present stream. The river bed itself varies from 1,000 to 3,000 feet in width, requiring at low water not over twelve hundred feet in the lower reaches.

The rock structure of south Missouri being of hard limestone, with occasional beds of sandstone, we naturally find a rugged surface and scenery varied and picturesque.

In north Missouri the rocks mostly belong to the Coal Measures consisting of sandstone, shales and clays, with but few beds of limestone; as a consequence the erosion has been very great and slopes more gentle. Along the margin of the Upper and Lower Coal Measures there is a well marked line of mounds from 80 to 100 feet high, generally capped with hard limestone with lower soft shale beds below. This limestone is generally the rock known as the Bethany Falls limestone. These mounds are sometimes near, while they may be separated by an interval of several miles. They form a graceful mountain-like line in the western part of Bates county, as seen from a distance. In Pike and Lincoln are other ridges and mounds parallel and between streams flowing towards the Mississippi. The summit consists of Lower Carboniferous limestone, with other older soft sandy and shale beds below, and Lower Silurian at the base. Here, as in the Coal Measures, the softer material has crumbled and been washed out, causing the limestones to drop down and leave gaps in the ridge. The result is fine distant views. There is no doubt but that the erosion was very great succeeding the building up of each Terrane, but the material helped to form the next. The various limestone formations have been successfully subjected to much dissolution and washing by underground channels, leaving extensive caves in many places. Especially, is this so among the Ozarks. The lower beds of the Ozark series include many large caves, for example those in Maries, Pulaski, Barry, Stone, Taney, Christian, Ozark, Oregon, Howell, Cam-

den, Morgan and others. It is said that there are sixteen caves in Stone county. The Upper Trenton limestone is also very cavernous as in Pike and Ralls, but the caves are small. The Lower Carboniferous also includes many caves, with some of large size, but none so large as those in the Ozark series. Such caves occur in the Burlington beds of Greene and Boone counties. The St. Louis limestone is very cavernous, but the caves are small, and their occurrence beneath generally produces funnel shaped sinks just above. Many of these occur in St. Charles and were formerly often seen where the present city of St. Louis now is, but most of them have long since been filled up. Fine springs are seen where the cavernous beds prevail, and south Missouri abounds in many large clear springs and the Ozark streams are all clear, full and rapid. Roaring river, in Barry county, originates in a bold cave spring, and the stream is a river at its origin. Spring river in southwest Missouri, in its entire course is swift, full and clear, with not often more than two and a half miles from the river to either watershed. It is mainly supplied by springs along its banks. One spring flows out with a stream 50 feet wide. A spring on Current river, Carter county, has a stream nearly as wide. So of other springs in Camden, Morgan, Phelps, Shannon and Wayne.

A few of the streams in southeast Missouri originate in bold springs, run a few miles in a natural exposed channel, then pass under ground for a half mile or more, and again appear to flow rapidly onwards. Such a stream is Wilson creek, Green county. Grand Gulf, Oregon county, is a deep winding canon with perpendicular walls 100 feet high at its beginning. Lower down it passes under ground, appearing again to disappear a second time, and then onward as a stream. A few streams are also spanned by natural bridges.

VERTICAL SECTION OF MISSOURI STRATA.

	Feet.
Permo-Carboniferous	180
Upper Coal Measures	1,180
Lower Coal Measures	640
Total Upper Carboniferous	2,000

	Feet.
Chester limestone and sandstone (Genevieve Group) St. Louis limestone	400
Keokuk limestone (Osage Group)	350
Burlington limestone (Osage Group)	
Chouteau Limestone.	
Vermicular sandstone and shales (Chouteau Group)	200
Lithographic or Louisiana limestone	
Devonian	100
Upper Silurian	100
Hudson River	120
Trenton limestone	200
First Magnesian limestone	100
First or St. Peters (saccharoidal) sandstone	130
Second Magnesian limestone	200
Second sandstone	125
Third Magnesian limestone	300
Lower Magnesian limestone and sandstone	300
Total	4,625

In southeast Missouri the downward extension of the Ozark series is about thus:

	Feet.
Second sandstone, lower beds cherty	125
Third Magnesian limestone with chert and quartz	225
Gritstone and Lingula beds.	50
Ozark Marble	25
Lower Sandstone and Conglomerate	90

The last rests upon granite or porphyry. The Ozark marble is red, flesh-colored, buff and variegated. It is found in Madison, Iron and Reynolds, and is generally inclined to the horizon.

The Lower Magnesian limestones, including the gritstone beds, contain the lead, nickel, cobalt and copper of these counties.

The Second sandstone, in south Missouri, contains irregular deposits of iron ore. The Third and Second Magnesian limestone contain both lead, zinc and barite.

The First Magnesian limestone is found just below the Trenton. At West Point, Ill., it is exposed seventy-five feet in thickness, and resting on the First sandstone. On Cedar creek, Boone county, it is sixteen feet thick, resting on the First sandstone, and overlain by the Devonian. I have not observed it in the Missouri bluffs west of Cedar creek. A few feet occurs on Muddy creek, Pettis county. Farther south I have not recognized it.

The Trenton, with Black river beds below, are occasionally seen on the Mississippi from Cape Girardeau to the Meramec, also on the Missouri bluffs, from St. Charles to Callaway, but no farther west, but are also quite prominent in the western part of St. Louis county. The Hudson river shales may be found in Lincoln and Pike, with other beds in Ste. Genevieve, Perry and Cape Girardeau. The Upper Silurian occurs in Cape Girardeau, Perry, Ste. Genevieve, Lincoln and Pike, and probably in Montgomery. The Devonian occurs in Ralls, Pike and Lincoln, and on the north side of the Missouri, from St. Charles county to Providence, being also well developed in the interior part of Callaway county. It is also found in Perry and Ste. Genevieve. Farther west a few exposures occur in Cooper, but no farther west nor southwest.

The Lower Carboniferous crops out beneath the Coal Measures, on the south and east of the Coal Measures, and occupies a belt of variable width from the southwest to the northeast, being more narrow a little west of central Missouri.

The Chouteau limestone lying just beneath the Osage series is well developed in Pike, Boone and Pettis, where by careful search many fossils may be found. These chiefly occur in the shaly beds between closely appressed limestone layers.

ORES AND MINERALS.

Following the above brief description of the formation, a few notes on the mineral wealth of the state would be proper.

Lead and zinc ores abound in southwest Missouri, where they chiefly occur in decayed, altered or cavernous strata, of the Lower Carboniferous, associated with calcite and dolomite. Jasper county affords over one-half the zinc mined in the United States. In other counties in southern, southeastern and central Missouri, the ores occur chiefly in the Third Magnesian limestone, and sometimes in the Second limestone. In central and southeast Missouri the ores occur both with calcite and barite and often in the southeast with quartz. Zinc is mined in the southwest and the southeast.

Zinc has been profitably mined in six counties with more or less mining in about a dozen counties, and favorably reported from 23 counties. Two counties, Jasper and St. Francois, contain remarkable deposits of galena and the St. Joe Mines in St. Francois county are as rich appearing as any mine in the world. The lead ores of Madison and St. Francois counties occur in our oldest sedimentary rocks, the lower beds of the Lower Magnesian limestone of the Ozark series, and these are often pure dolomites. Nickel, cobalt and copper occur associated with the galena, and the ores occur in flat sheets between the limestones or else disseminated through the limestone beds as replacement deposits.

Coper has been mined with some profit in St. Genevieve county, and other deposits have been opened in Phelps, Shannon and Crawford. In these counties it occurs in rocks of the Ozark series. In Dade and Greene it occurs in rocks of the age of the Lower Carboniferous.

Nickel and cobalt have been mined in Madison and St. Francois counties where the ores are associated with lead ores. Millerite in beautiful hairlike crystals has been found in the quarries of St. Louis, associated with Fluorspar, calcite and dolomite. Iron ore has been found in one-half the counties of Missouri, and has been mined in six counties. It occurs as a specular oxide in porphyry, and a similar ore in sandstone of southern Missouri. Limonite occurs in pockets in sandstone of south Missouri.

Profitable deposits of red paint clays occur at many of the iron banks of south Missouri. Purple and red clays are often interstratified with Coal Measure shales. Abundant supplies of fireclay occur throughout the Coal Measures. Mammillary forms of quartz abound in Madison, St. Francois and Washington. The Ozark series and Lower Carboniferous in many places exhibit excellent layers of building stone. The granite quarries of Madison, St. Francois, Iron and Wayne furnish excellent varieties. Perhaps no state has sandstone of better quality nor in such abundance as we have in Missouri for glass making.

COAL MEASURES.

In the eastern part of north Missouri the strata generally occupy nearly a horizontal position with a surface elevation of not much over 900 feet above the sea. West of Chariton river there is a gentle dip to the northwest, the surface in Nodaway county is about 1,200 feet above the sea, and allowing for northwest dip and conditions of superimposed beds, the surface rocks of Linn county may be as much or more than 1,000 feet below the surface basis of the western part of Nodaway county.

In western Missouri, as far as heretofore observed, the Coal Measures rest on some member of the Osage series. The rocks of the Coal Measures include 24 7-10 per cent of limestone, 37 3-10 per cent of sandy beds and 36 5-10 per cent of clay shales leaving 1 4-10 per cent of coal.

The Coal Measures underlie an area of 23,100 square miles, including about 12,000 square miles of exposed lower measures. Within 8,000 of this area coal may be mined either at the surface, or at easy workable depth, including an aggregate of 22 feet total thickness of the coal beds. The southern and eastern boundary of the Missouri coal fields follow an irregular line from Jasper county in the southwest through Jasper, Barton, Dade, Cedar, Vernon, St. Clair, Henry, Benton, Pettis, Saline, Howard, Boone, Callaway, Audrain, Mongomery, Ralls, Monroe, Shelby, Knox, Adair, Schuyler, Scotland and Clark counties. Other small coal areas occur in Lincoln, St. Charles and St. Louis counties. The Lower Coal Measures represent a thickness of 670 feet and include all of our workable coal beds that are of value. The thickest coal of two or three feet is mined in the counties of Barton, Vernon, Bates, Henry, Johnson, Chariton, Howard, Randolph, Macon, Adair, Putnam, Schuyler, Boone, Callaway, Audrain. Other beds not quite so thick are mined in the adjoining counties. Apparently the best coal is found in southwest Missouri. The Upper Coal Measures lie in the northwest, and rest upon the Lower Measures, which latter dip northwest beneath the Upper. The Upper Measures

include about 1,300 feet thickness of measures, of which 170 feet, found in Atchison county, contain fossils similar to those found in the Lower Permian of Kansas, and for that reason may be referred to the Permo-Carboniferous. In this 170 feet I have only observed two inches of coal. The remainder of the Upper Coal Measures includes over 1,100 feet thickness, but with this thickness and an area of nearly 1,100 square miles, the total aggregate is only four feet of coal, and with only one workable seam, varying from six to sixteen inches in thickness. Other coals are represented by mere streaks. The eastern limit of the Upper Coal Measures is an irregular line, beginning in the northwest part of Bates county, thence northeastwardly to northwest part of Johnson county, thence northwardly, including the hills facing the valleys of Sniabar, thence via Swanwick, Ray county, to the eastern part of Livingston and western part of Sullivan counties. In the northeast part of Sullivan there are certain beds which may belong to the Upper Coal Measures, as well as other beds near Milan. The line between the Lower and Upper Coal Measures is generally well marked, and may be traced out by line of mounds, nearly following the direction of the boundary, and also recognized by a well-known stratum known as the Bethany Falls limestone, forming a prominent escarpment from the southwest to the northeast. At its farthest southern extension it caps the hills at the head of Mulberry creek, Bates county, is well exposed at Parkerville, caps the hills west of Archie, at Freeman, and at Pleasant Hill. It lies near railroad at Westline. It is favorably exposed near Lone Jack and Pink Hill, at Greenwood, and hills near Little Blue. It lies at edge of water at Kansas City and Randolph. It is the highest rock on head waters of Blackwater, Johnson county, and at Chapel Hill, and caps the ridge north of Odessa, and crops out half way up the hill at Missouri City. Farther north the escarpment may be seen on Shoal creek, Caldwell county, in railroad cut at Mooresville, and at Springhill, the western part of Sullivan and eastern part of Harrison, and southeast of Princeton. The Bethany Falls limestone includes a little more than 20 feet thickness of

limestone, the upper part of a dove color, and often breaking into angular fragments. It forms a waterfall at Bethany in Harrison county. I used the term "Bethany Falls Limestone" in an article written in 1860 and published several years after in first volume of Transactions of St. Louis Academy of Sciences. I also used in Geological Report published in 1873, and recently other geologists have recognized its appropriateness. The middle beds are often oolitic, and this character has been recognized at distant places, for example, at Pleasast Hill, Greenwood, Kirtley's quarry near Mooresville, and near Princeton. Just below the Bethany Falls limestone there is about seven feet of shales and thin limestone layers, then six feet of gray and ferruginous limestone, one layer of which is also oolitic. This limestone I consider the base of the Upper Coal Measures. It is well exposed near Pleasant Hill and Lone Jack, also near Liberty, Clay county, and is the highest rock on bluffs of East Fork of Grand river five miles north of Chillicothe. It is also well exposed in the eastern part of Harrison county, where it occurs a few feet above a thin coal bed.

OIL AND GAS.

Bitumen is occasionally found in western Missouri, from Caldwell county on the north to Newton county, a distance of about 175 miles and within a width of 25 to 40 miles, seemingly in greater abundance from Bates county southwardly, and extending into the adjoining portions of Kansas. In the southern extensions of this district, tar springs are occasionally observed. From 1864 to 1867 there was quite an oil excitement in western Missouri and about six wells from 700 to 800 feet in depth were bored for oil in the counties of Ray, Jackson, Lafayette, Bates, and wells of lesser depth in other counties. The *incitive* for boring at these places was the finding of rock, generally sandstone, from which drops and weak flows of bitumen issued. But this black tarry substance was in most cases only found in the rocks near the surface. None was found at any great depth below.

In the counties of Bates, Vernon and Barton most of the rocks, as well as the coal, contain bitumen, often free, easily detected by sight and smell, and is often seen oozing as black drops from the rock and is sometimes found occupying cavities of fossils. The rocks are sometimes only slightly darkened by it, while at the same time they seem to be rendered more tough by its presence. In some of the mines of Jasper county it is intimately associated with the ores. Its greatest geological extent in Missouri is 6,000 feet vertically, averaging probably 300 being stored chiefly in the Lower Coal Measures, but sometimes found in the Lower Carboniferous. In its northern extension, as far as known, it is confined to the upper sandstones of the Lower Coal Measures.

Gas, sufficient for illuminating purposes, has been found in several wells of Kansas City, also in Cass, Bates, Vernon, and in some of the adjoining counties as well as in the adjoining state of Kansas. But many wells have been bored in western Missouri without finding either oil or gas. I do not think that the oil is stored up in sufficient quantity anywhere in Missouri to pay for the boring.

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ERRATA.

On page 378, about the middle of the page, omit "s" after mile.

Page 379, about the middle of page, "The sub-carboniferous," etc., should begin a new paragraph.

Page 379, omit comma after "Acervularia," in the second line; also, in 7th line from bottom, omit letter "d," after "an," between "Rhynchonella" and "Orthoceras."

Page 380, in top line, for "Auloporo," read "Aulopora."

Page 382, 5th line from bottom, for "Commers," read "Conners."

Page 384, in the condensed section near the middle of the page, in No. 8, for "1 foot of Clay," should read "1 foot of coal."

In Article on Ozark Uplift, etc., on page 398, 8th line from bottom, Chester should begin with a capital "C."

On page 394, in last line, insert the word "geologically" after "are."

Page 395, in 13th line from bottom place a comma after South, and insert "ai" in place of "of," just before Crystal City.

Page 398, in 8th line from top for "porpyries" read "porphyries."

Page 402, in first line of the lower paragraph for "Southeast," read "South."

Page 402, near bottom of page, put a question mark after Permo-Carboniferous.

Page 403, near the top, a bracket should be placed including Keokuk and Burlington, also another bracket to include Chouteau, Vermicular and Lithographic, just before the figures.

Page 405, in 13th line for "coper," read "copper."

Page 406, in 6th line, a period should be after northwest and next word begin with a capital.

Page 406, near end of 1st paragraph, for "basis" read "beds."

Page 407, seventh line from top, for 1,100 square miles read 11,000 square miles.

Page 408, ninth line from top, "Pleasast" should be "Pleasant."

Page 409, in ninth line from top, "6,000" should be "600."